# CHEMISTRY IN HEALTH

SIXTH EDITION

# AND DISEASE

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#### PREFACE TO THE SIXTH EDITION

THE Sixth Edition of Chemistry in Health and Disease represents no change in the size of the book. This was accomplished by carefully evaluating the Fifth Edition, and then deleting and condensing some of the subject matter to provide space for new material and for added emphasis on several topics. The first two chapters in Part II, Organic Chemistry, have been expanded to three chapters, and the material has been largely rewritten and reorganized. This has been done because the fundamentals of Organic Chemistry are becoming increasingly important for an understanding and interpretation of the chemistry of body processes, both in health and disease. The topic of colloids, in the chapter on Solutions, has been extensively revised for this new edition.

The features that contributed to the wide acceptance of the previous editions by both students and instructors have been retained for the most part in the present revision. A chapter outline, useful to both the student and his instructor, is placed at the beginning of each chapter. The self-testing questions interspersed throughout the text provide the student with a means of determining his or her understanding and retention of the subject matter. Included in the "Suggested Activities" at the end of each chapter are: "Thought-Provoking Questions," "Vocabulary of New Terms," and "Topics for Oral or Written Reports." Following Parts I, II, and III are reviews of definitions and meanings of significant terms. The laboratory exercises constitute Part V of the book, and they are correlated with the chapters. Part IV consists of an appendix containing charts, tables, and other organized data useful to the chemistry student.

The objective of the Sixth Edition, as of prior ones, is to give the student a foundation in chemistry which will include the necessary chemical facts and theories important in an intelligent approach to the study of health and disease. Suggestions and criticisms from instructors who have examined this book have always been welcomed, these are valuable guides for revisions Grateful acknowledgment is given to Dr Alfred H Free, chief chemist and head of the Biological Department of the Miles Laboratories, for the chapter on hormones Suggestions from numerous correspondents, especially Sister Veronica, of Good Samantan Hospital, Dayton Ohio, have helped greatly in making the text what it is The authors also wish to express appreciation to the staff of the  $\Gamma$  A Davis Company for continued cooperation, and to numerous individuals and organizations to whom they are indebted for permission for use of certain illustrations, as acknowl edged throughout the book

HARRY C BIDDLE

#### PREFACE TO THE FIRST EDITION

THERE are many life situations in which an applied course in Chemistry is needed. In such instances, all of the ramifications of the science, such as its applications to the industries, are not needed. The medical student, for instance, is very much concerned with biological chemistry, as is the dietitian and student of nutrition, as well as the nurse. Again, there are many public health workers, and numerous technicians of various kinds who are not nurses, and yet are concerned with the application of chemistry in Health and Disease. It is true, that of all such groups, the nurse is the most vitally interested in such an application of Chemistry as that presented in this text.

The author feels that students taking an applied course in Chem istry need only a minimum of inorganic chemistry, especially as the importance of physiological chemistry is being more and more emphasized. At first glance, an instructor may feel that some topics in inorganic chemistry have been entirely eliminated from the text, whereas they are sufficiently covered in the Laboratory Work provided for each chapter.

Chemistry in Health and Disease has been divided into three major sections inorganic, organic, and biochemical. The inorganic section is, of course, a necessary review for the entering student, however, it has been made into a functional discussion, as a consequence this section contains much useful information not ordinarily contained in many texts dealing with elementary inorganic chemistry. More over, since practically all of the principles of chemistry are considered in morganic chemistry, this branch of chemistry must as sume a prominent place in any text of this kind

This text provides sufficient material for a sixty to a ninety hour course and it presents a more extended development of organic chemistry than is given in any other similar text. That the student who has not had much of a background in organic chemistry might

better understand the principles of biochemistry, more than the usual discussion has been allotted to the development of organic principles, and in particular the chemistry of the carbohydrates fats, and proteins. Much stress is laid upon biochemistry, which of course includes the chemistry of the blood and of the excretory products of the body, as well as chemical changes involved in metabolism, the role of vitamins in nutrition, and the chemistry of milk and other food products. More attention has been given to the chemical changes taking place in the body than has hitherto been presented in a text of this character.

It is a pleasure to acknowledge the author's indebtedness to Dr Ceal E Boord, Professor of Organic Chemistry, Ohio State University, for his constructive criticism of the chapters included in the organic section of this text, and to Frederic T Jung, Ph D, MD, Associate Professor of Physiology, Northwestern University, for the improvement resulting from his criticisms of the chapter on Metabolism.

My sincere thanks and appreciation for the improvement of this text are due Dr. Anthony Sindom, Jr., of Philadelphia, Pa., for his excellent fund of information and his personal contribution in writing the chapter on Vitamins.

Especial appreciation should be expressed to Miss Marion G Howell, Dean of the Frances Payne Bolton School of Nursing, Western Reserve University, who made possible the opportunity

to present this material in manuscript form to the author's classes

# AN EFFECTIVE METHOD OF STUDYING CHEMISTRY

Since the greater part of the time devoted to any course is spent in preparation, it is necessary that the student form correct study habits for the assimilation of textbook material. In undertaking a study of any subject one certainly must have a knowledge of the objectives involved. These include the nature of the subject matter to be mastered, and a clear understanding of the facts and principles needed for dealing with the problems embraced in the subject.

Some of the factors in an effective method of studying chemistry have been established by an investigation of the study habits of numerous students who were successful in mastering this science. The following outline of the objectives in this course, together with suggestions for more effective study, should prove helpful

#### I. FACTS AND PRINCIPLES

- (a) To know that many of the happenings in everyday life as well as hospital procedures are the result of chemical changes, and that our very existence depends upon them.
- (b) To understand the electrical nature of the atom and the principles in volved in chemical changes
- (c) To know the properties, uses, and behavior of certain elements, compounds, and classes of compounds
- (d) To have a better understanding of the place and possibilities of chemistry in health and disease

#### II. ATTITUDES

- (a) To develop a growing understanding of the practical applications of chemistry which furnish so many modern comforts
- (b) To have a desire to select and learn the facts and principles which are necessary for the understanding of chemistry in the field of nursing
- (c) To appreciate the value of health and to demand pure foods, drugs, and other substances necessary to health and social well being
- (d) To appreciate the numerous applications of chemical changes

- (e) To develop a desire to learn the fundamentals of chemistry to the end that the current literature relating to the nursing profession may be read intelligently
- (f) To develop an appreciation of the contributions that chemistry makes for the student's full development

#### III HOW TO STUDY

#### Study Where There Are No Interruptions

It is much easier to concentrate where it is quet, and where there are likely to be no interruptions. In other words the right environment not only assists you in developing good study habits but aids in conserving time, and time is one of the most valuable things infel. Each individual his 24 hours per day, no one has more. Time must be used where it is found. You cannot berow to hours from today and use it comortow. Also time lost can never be regained. For these reasons plan to use your time wealy. Plan your work and then work your plan. Make a class and study schedule, and adhere to it Experiences of student nurses indicate that finding sufficient time is a most unportant mobilem.

#### Consider the Value of the Subject

Before beginning to study ask yourself whether the subject matter will be useful to you not only in succeeding courses but also in the future practice of your profession. Only in this way can you stimulate and arouse sufficient interest to have a desire to master your assignments. If at any time interest lags and day dreaming begins think again of the hardicaps that must be over come by a nurse who is lacking in the fundamental jornicles of chemistry.

#### Acquire a Bird's eye View of Each Assignment

For those students who have had some previous training in chemistry it will be sufficient to read the Chapter Outline at the beginning of each chapter in order to gain a survey of its subject matter but for those who have had no previous chemistry it will be necessary to read not only the paragraph headings but perhaps the entire chapter. This should be done rapidly The object is to gain a general idea of the main points of this chapter before beginning to study its details.

#### Make an Analytical Reading of Each Paragraph

(a) Underscore the main points or make a marginal note of them (b) Give special attention to italicized words (c) Learn the meaning of technical words such as atom and electron (d) Build a vocabulary of chemical words for quizzing purposes (a) Master a paragraph before Proceeding to the next one

#### Question Yourself on the Contents

Go back, and after looking at the paragraph heading try to recite its essential facts or check your accomplishment by the Self Testing Questions Repeated

recitation is a more effective method of remembering than merely reading the assignment over and over again

#### Prepare for Tests:

Make up questions (preferably completion type) covering the main points and those other points which you would bring up if you were the instructor Sometimes it is an advantage to be quizzed by another student. The next best practice is to answer the author's questions

#### Study Plans:

(a) Go over your assignment or lecture notes the day they are given. This enables one to remember and plan for study time. (b) Study the assignment the day before going to class. (c) Review underscored lines, italicized words, and your notes the next morning, or ust before going to class.

#### IV. IMPROVING YOUR MEMORY

Everyone spends hours trying to remember things Maybe it's a name, some statement you read, or something you were supposed to M You try to con centrate, to pull the thought out of the recesses of your mind. But there are no real muscles that you can use to draw a memory from the past. The harder you try to remember in that manner, the more likely you are to forget. To illustrate, suppose that when being introduced to someone, you are aware of the blue color of his suit his red necktie and his mustache. Later, in trying to remember his name, you think of these details and what happens? You cannot receil it Why? Because your mind is crowded with these details that only serve to detract from the name you want to remember. There has been no association between the man and the name.

#### Association Aids Remembering

Instead of this hapharand method, make these details help you Immedi ately following the introduction, begin to the them all together by associating them with something definite about the person. They will have a tendency to stay together. Then, when one fact comes into your mind, they are automative cally all brought to the surface. If the mark's name in the above incident was Skye, for example, it would be a simple matter to associate the name Skye with the blue color of his suit by merely associating blue and Skye Blue Skye. It sounds saily, but it does and remembering. In this simple plan for remember ing, you have pictured a detail you wish to recall Mind pictures are more easily remembered than anything else. To recall snything, you must first give sufficient attention to the facts you was to remember, and second, learn as many related facts and ideas as you can, so that any one will recall all the others.

# How to Retain What You Read and Study-

Sometimes you find after reading a page, your text for example, the inability to recall a single line. The usual reason is that you have read too rapidly, skipped words here and there, let your mind wander occasionally about some

thing else or maybe were not in the right frame of mind, worried for instance To overcome one or more of these bad reading labits especially lack of concentration and be able to retain textbook material for example you must

First Learn to read slowly, only one thing at a time (no skipping), and keep your mind on the understanding of each sentence before passing onto the next sentence. By reading slowly your mind's eye can coordinate with your visual eye and then you will have a mental moving picture of what ideas the author is presenting, a principle long ago presented when the Chinese stated that "One picture is worth a thousand words". To retain what you wish to remember you must use a mental moving picture of what you want to remember and associate it with something that is already present in your mind

Second Underscore the main points or make a marginal note of them

Third Check your retention by raising your eyes at intervals from your resding and find out how much you can recall. If unable to make a rapid mental moving picture, a glance back at the reading will let you know how well you are concentrating and retaining the subject matter. And for emphasis again you must understand and matter a paragraph before proceeding to the next one for if you cannot next one for if you cannot next one for if you cannot also that happened your reading, which change do you think you will have of remembering in a coming recitation or written test?

Fourth Frequently glance back over the main points and at future times acquire the habit of reviewing. Interval reviewing to memorize requires about one half the time as does one reading.

#### Sometimes You Forget in Order to Remember

However, it after really learning something, you still cannot recall it try hard to forget it, the secret of accomplishment being to expel it by substituting a more powerful thought. Clear your mind of what is blocking it, and keen it releared.

Sometimes you will make an intense effort to quickly recall something, and succeed in doing it. But the next time you will find it harder to recall. You may even be unable to recall it at all. This is due to overloading your mind with president details.

When the trick of forgetting unrelated details becomes part of your mem ory method, you will amaze yourself with the variety of things you can recall Your very efforts thus far have hidden them from view If you can't recall something at once, leave it alone, do something else so you will forget it Later, try a second time If that doesn't work start forgetting sgain. Once this becomes a habit, you will have no difficulty in receiling instantly almost anything you once learned.

#### There Are Three Laws of Memory

INTEREST is the first of three great laws of memory You can learn any thing that you are sufficiently interested in. Since learning is necessary for remembering, the deeper the interest, the more readily you can remember

The student who can't learn chemistry or any other subject is not very much interested in it. Chances are very little will be remembered unless interest is aroused. Selection is the second great law of memory. If you did not forget almost everything, you could not remember anything. Of the countless impressions received by your mind every hour, it is necessary to retain only a select few. Otherwise your mind would constantly be in a state of chaos. Building up a strong memory does not mean remembering everything.

ORGANIZATION is the third and most important law of memory You must center your knowledge around one definite goal, hursing, for example,

and keep it in mind always

From this we can see how all three laws—interest, selection, and organiza ton—depend upon each other, and must work together to give you knowledge and a strong memory

#### Immediate Reviewing Saves Hours of Study

Acquiring the habit of review is of major importance in improving your memory. When reviewing anything you want to remember, do it at once, the same day. Otherwise, you will spend two or three times as long the next day. Re-read it a day later, and, after a week, a quick glance at it will suffice to refresh your memory.

As a matter of future consolation, your memory does not become dim with age. It takes you longer to organize your thoughts but your mental power is the same.

#### INTRODUCTORY NOTES

#### TO THE INSTRUCTOR

It may be helpful to offer, briefly, what has been found to be a very satisfactory method of presenting the subject of Chemistry to student nurses. The nature of the work expected, and some of the things required of the student, may be presented to the students as a preliminary to beginning the study of chemistry. It is not advisable, however, to reveal all that will be expected of the chemistry student, any more than it would be to try to tell a child all that life expects of him. Many things should be presented gradually, and as the work progresses, otherwise the student may become confused and discouraged.

#### CLASS WORK

(1) The Textbook: A textbook is an educational tool. No attempt should be made to use such a tool until the student becomes familiar with it. Explain the organization of the book, beginning with the table of contents. Show the principal divisions of the text and their nature. Now examine one of the chapters showing its organization, its preliminary material, its lesson plan, and its study aids at the end of the chapter.

The first division of this text, Inorganic Chemistry, takes up some of the accomplishments of chemistry in providing for greater health, comfort, and leisure. It gives (1) a somewhat elementary conception of the meaning of chemistry, (2) some idea of the accomplishments of the chemist in a changing civilization, (3) an understanding of the chemist's working terms, (4) a mental conception of the electrical nature of the atom and its behavior in chemical changes, (5) a knowledge of the properties and uses of oxygen, water, acids, bases, salts, and certain nonmetallic elements, and (6) the behavior of these elements or compounds under varying conditions.

The second division of this text, Organic Chemistry, stresses concentration on certain type reactions applicable to each of the homologous series mentioned. The type equations, together with the examples which accompany them, illustrate the chemistry of other members of the series. In this way students become familiar with the characteristic properties of each series, and do not have to learn too many equations other than the type equations.

The third division of this text, Biochemistry, aims only to give students the essential background and facts necessary to understand and evaluate any future accomplishments in this field of work

This text is designed to enable students to study without any interpretation on the part of the instructor, thereby stimulating the student's interest. Human interest is one of the major principles of education, and without it one remains a poor student.

Interest is the essence of scientific thinking Teaching difficulties, as usually met, are made somewhat easier by introducing practical

helps for both student and instructor

there are special topics and suggestions

The outline at the beginning of each chapter simplifies and classifies the subject matter

The "self testing" questions at the end of the natural breaks in each chapter are such that when properly answered they will assure the student that the minimum essentials have been mastered. The "thought provoking" questions in the Suggested Activities are primarily for those students who can think in the realm of chem sitry. These questions are mostly of a practical nature, and have been asked with a view not only of fixing the basic facts developed in the text, but also to enable the student to solvefuture problems based upon these principles. Since the answers are not directly stated, these thought provoking questions should develop individual thought and research on the part of the student. To provide further for individual differences and to facilitate individual work

The important technical words or terms as they first appear in the discussion are listed at the end of each chapter under the title, "vocabulary testing of new terms" This list will be helpful to students who have formed the habit of looking up words that are not familiar to them

The "topics for oral or written reports" are primarily for students who are capable of doing additional work, especially for those who have had a year's work in elementary chemistry. The reference books and periodicals listed on page 633 should prove helpful as sources of material for such reports. These references, and others, are to be found in most science libraries.

Interest in the course will be aroused by asking the pupils to present any chippings from current periodicals of a chemical nature. These should be signed by the donor and attached to the Chemistry Bulletin Board

The illustrations, far in excess of those in other texts of this

nature, have been selected with a view to stimulate interest and motivate thinking. In this way chemical principles and their applications are visualized by the student, thus adding to the clarity of text explanations.

From the above statements it should be evident that the text has been organized not only to aid the student, but also to assist the

instructor in his teaching problems.

(2) ASSIGNMENT: Go over the main points covered in the assignment, emphasizing important parts, pointing out difficulties, and showing some of the practical applications.

- (3) Tests: Tests are conducive to study-habit formation. Have ready two mimeographed sheets, A and B, each containing a dozen or more questions of the one-word answer, the multiple-choice, or the matching-answer type. The tests should review the past class and laboratory work, and cover also the assignments of the day or week. Following the assignment, and previous to the lecture-recitation, give every alternate student the same set of questions. It will be evident that these tests will be a check of the student's review work, and the preparation for the advance assignment. Further checking is made possible by mid-semester and term examinations. After collecting the papers, immediately review the tests.
- (4) Lecture, Rechation, and Demonstration: Follow up the review of the test by discussion of further points brought up in the assignment for the day or week. This may consist of lecture, informal questions, or discussion by the students. Lecture, accompanied by demonstrations and recitations, is an effective method for class work. The extent to which each of these different procedures is used will depend upon the lecturer and the size of the class, as well as the preparation and previous experience of the students.

# STUDY ASSIGNMENTS

Since textbook assignments depend upon the number of hours allotted to the course, and the previous training of entering students, the following assignments are suggested:

(1) For a short course, with all of the students having been care-

- (1) For a short course, with all of the students having been carefully selected, the first eighteen chapters offer sufficient material for two hours of lecture-recitation and one laboratory period per week. This will constitute a sixty-hour course.
  - (2) For a short course when the time allotted for the course is the

same as in (1), but when all of the students have had the equivalent of a good course in high school or college chemistry, practically the entire text can be covered. This can be accomplished by reviewing the discussion part of the first eleven chapters (Inorganic) and selected parts of the laboratory exercises in the recitations and the laboratory assignments. Such a rearrangement will then allow these students extra class and laboratory periods for covering the organic section, and selected portions of the biological section. If pressed for time, the chapter on Blood and Lymph and the chapter on Hormones may be omitted as these subjects are treated in physiology. Also the chapter on Vitamins and Milk can be considered in nutrition. This then will constitute a sixty hour course.

(3) For a long course there is sufficient material in the twenty three chapters to cover one semester's work by assigning individual chapters, including the 'Suggested Activities' 'Such a course will be suitable to schools of nursing which are affiliated with universities It will constitute a ninety hour course

#### PART I

# INORGANIC CHEMISTRY

The division of chemistry that deals with the study of lifeless or unorganized materials excepting those containing carbon, and includes the general principles underlying their transformations

Technique for the administration of radioactive gold. Notice the heavy walled storage container from which the radioactive material is being removed. Courtesy Medical Division. Oak Ridge Institute of Nuclear Studies. Inc.



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#### SOME FUNDAMENTAL FACT:

#### CHAPTER OUTLINE

- I CHEMICAL CHANGES
  - (a) Analysis and synthesis (b) Factors influencing
  - chemical change (c) Physiology correlation
- II MATTER AND ENERGY (a) Two states of energy
  - (b) Chemical energy (1) Its conservation (c) How chemical energy is
    - measured (d) Energy value of foods

- III ELEMENTS AND THEIR OCCURRENCE
  - (a) Elements the basic forms of matter
  - (b) Metals and nonmetals (c) Importance of elements
    - (1) In the earth s crust (2) In the human body
  - IV COMPOUNDS AND MIXTURES (a) Compounds
    - (1) Law of definite composi tion
    - (b) Mixtures (c) Pharmacology correlation

#### I. CHEMICAL CHANGES

From remotest antiquity the thoughtful observer has been im pressed by the fact that the different materials in nature about him are frequently undergoing changes The burning of wood probably first attracted the attention of man as one of the greatest changes (Fig. 1) As the original wood burns, heat and light are produced, and finally nothing visible remains but a few ashes The rusting of metal, the souring of milk, the decaying of fruits and meats are further striking examples of these chemical changes Foods undergo



Fig 1-Chemical Change The campfire illustrates one of the best known chemical changes, i.e., burning. What are two man products of burning? Courtesy, H. Armstrong Roberts Philadelphia

complicated chemical changes in the body. All processes for cooking in olve chemical changes which not only make foods more palatable but also more digestible. The white of an egg, for example, is rendered more palatable by converting it into a soft white solid. The study of changes in the composition of matter, and the energy transformations which accompany such changes, is the science of chemistry.

# **Analysis and Synthesis**

If we apply fire to the wick of a candle we first observe that light is produced and then we notice heat is being generated. The candle is a poor medium for illumination because it produces more heat than light. Continued observation now informs us that the candle is disappearing.

If we hold a clean, dry inverted bottle over the burning candle, moisture will be seen to condense upon the inside of the bottle, which indicates that water (H<sub>2</sub>O) is being formed. The abbreviated writing of water as H<sub>2</sub>O means that water is composed of two parts of hydrogen and one part of oxygen

Now, if we lower the inverted bottle over the burning candle, the flame finally goes out The invisible gas left in the bottle, if shaken up with some clear limewater, forms a milky white liquid We know that we exhale carbon dioxide, CO<sub>2</sub>, and this gas also gives this same test when by means of a glass tube we blow through limewater. We therefore conclude that carbon dioxide is also in the invisible gas formed when the candle burns. Further, we have been taught that oxygen in the air is necessary for breathing, and for the burning of any material, therefore if the oxygen in the H<sub>2</sub>O and the CO<sub>2</sub> came from the air, the candle must have been composed of hydrogen, H, and carbon, C, and perhaps oxygen O. By finding that the substance of the candle contains hydrogen and carbon we have illustrated a process called analysis.

The opposite of analysis, i.e., the combining of substances to form a new substance, is called synthesis. Thus the combining of hydrogen and oxygen to form water is called the synthesis of water.

In all chemical changes the composition of the original substances has changed, and energy has been evolved or absorbed. If a change takes place wherein the composition is not altered (when you can still recognize the substance by some of its descriptive properties as the original substance with which you started), then the change is a physical change. No new substance is formed. In bending the arm, both physical and chemical changes take place (Fig. 2). In

the physical change, the voluntary muscle becomes harder, thicker, and shorter, while the cells are altered in size and position. The chemical change is primarily the result of the oxygen in the blood reacting with the sugar and fat. The proof of these chemical changes is evident in ordinary exercise. As the result of the in-



Fig. 2—Chemical Change in Muscles. In bending the arm both physical and chemical changes take place. What always is produced by a chemical change?

ternal and external work of the body, heat, a form of energy, is produced. Strenuous and prolonged exercise leads to an accumulation of lactic acid in the tissues, contributing to fatigue.

## Factors Influencing Chemical Change:

As the study of chemistry is continued it will be apparent that there are factors which promote chemical changes and affect their rates. Heat, light and electricity, all of which are forms of energy, are widely used for bringing about chemical changes. Catalysts, substances capable of changing the rates of chemical reactions without themselves undergoing any permanent chemical change, are important agents, and numerous examples of these will follow.

# Physiology Correlation:

What are the chemical changes producing muscle fatigue? What is derived from these chemical changes? Review the subject of fatigue, its causes and preventives. Chemically, why does eating sugar relieve fatigue? What have ventilation and perspiration to do with fatigue, and why is salt added to the drinking water of those whose labor produces profuse sweating?

#### SELF-TESTING QUESTIONS

Note: At frequent intervals throughout the text, questions are inserted to serve as a quick checking device. If answered correctly they indicate

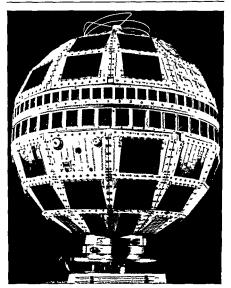


Fig. 3—The Telstor II Communications Satellite Built by Bell Telephone Laborato ries. There are 3600 solar cells on its surface for transforming solar energy (light) into electrical energy. In what ways may satellites of this type prave useful to the medical profession? Courtery, American Telephone and Telegraph Company

the mastery of the preceding section. Answers should be written out, whether or not the questions are assigned. They will serve later as a general review, prior to final tests.

- 1 What does the study of chemistry involve?
- 2 Define and give an example of analysis and of synthesis

- 3 What is the test for carbon dioxide?
- 4 What are three ways of recognizing a chemical change?
- 5 What three forms of energy may bring about chemical changes?

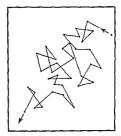
#### II. MATTER AND ENERGY

In all chemical changes we deal first with matter, which is defined as anything occupying space and possessing weight, and second with changes which we call energy changes. By energy we mean the ability to do work, or to maintain motion in spite of opposing forces. Any form of matter—solid, liquid, or gas—possesses energy since it can always be placed in condition to do work. Fuels such as wood, gasoline, or gas possess energy since, when burned, they can do work by operating engines to produce motion. In fact, matter is energy in another form (Einstein). Familiar forms of energy are light, heat, sound, electrical energy, and chemical energy.

# Two States of Energy

In winding a clock spring, pumping water into an elevated reser voir, or lifting a heavy weight, work has been done and energy has been stored. This form of mactive energy which a system or group of bodies possesses by reason of position or configuration is called potential energy. Under changed conditions this energy can be released to do work. Potential energy can be transformed into energy of motion, which is called kinetic energy. This is the type of energy possessed by particles (molecules) moving at random (Fig. 4). In a hot body there is violent agitation and collison of the particles, while in a cool body they move more slowly. Energy of motion is usually dissipated as heat

Fig 4—Particles (Molecules) in Mot on. The constant collis on of minute moving part cles (malecules) with other part cles produces a motion in short, straight I nes. Why do the particles have erratic motions?



# Chemical Energy:

Foods and fuels and all chemical substances possess potential energy which becomes available as heat or kinetic energy when chemical changes take place. Sometimes these energy changes become the most important part of a chemical reaction, and changes in the composition of matter are brought about with this end in view. For example, some of the food taken into the body is "burned" to give heat and mechanical energy, while some is used for building body structures. However, we burn fuels in a furnace to produce heat only. In this course we are particularly interested in the chemical energy stored up in foods. This results when energy from the sun (solar energy) is utilized by plants, through the agency of chlorophyl (klo'ro-fill), to synthesize carbohydrates. etc. Upon "burning" these foods in the body there is again released the same amount of energy which the sun supplied in producing the food. This energy is used primarily to keep the body at the normal temperature of 37° C. (98.6° F.), the necessary temperature for chemical changes which take place in it Only a small amount of the energy from food is used to supply the body with mechanical energy, which is manifested by cell movement; most of it is used to keep the body at normal temperature. All experimental evidence points to the conclusion that energy can be transformed from one form to another without loss. These facts are usually expressed as the Law of Conservation of Energy, a law which states that energy can neither be created nor destroyed, but may be transformed from one form to another.

#### How Chemical Energy Is Measured:

As chemical energy generally appears as heat energy we use heatenergy units to measure chemical energy. In the metric' system of measurement, the unit of heat energy is called a calorie (small). which is defined as the amount of heat required to raise the temperature of one gram of water one degree, centigrade,

In physics and chemistry the calone (cal.) is used; but in nutritional studies the "large calorie," spelled with a capital C and

<sup>1</sup> The metric system of measurement is generally used in all scientific measurements The unit of length is the meter (39 37 inches), which is divided into 100 centimeters. The unit of volume is the liter (1 05 quarts), which contains 1000 milliliters. The unit of weight is the gram, which is the weight of 1 milliliter of water at 4° centigrade. One liter of water weighs one kilogram (2 2 pounds) Remember

1 meter = 100 centimeters (cm) = 1000 millimeters (mm)

1 her = 1000 millimeters (lo.)

<sup>1</sup> kilogram = 1000 grams (Gm.)

<sup>-</sup> weight of 1 ml, of water at 40 C.

equivalent to 1000 small calories, is the only one used. It is often called a kilocalorie. One of the best examples of a material contaming chemical energy which can be transformed into heat energy is coal. When a man buys a ton of coal, he is interested in the amount of heat he has bought. By burning a sample of coal in a special apparatus, called a calorimeter, and by utilizing all of the heat generated to heat a weighed quantity of water, the number of heat units can be determined. In this country, fuel engineers generally use instead of the calorie a heat unit known as the British Thermal Unit (B.T.U.), and define it as the amount of heat required to raise the temperature of one pound of water 1° F. (See Fig. 1, p. 497.)

#### **Energy Value of Foods:**

As previously indicated, the energy in foods has a certain calorific value as does coal Sometimes, we are likely to overlook the fact that the foods we eat undergo chemical changes in the body with the formation of new living tissues. An outstanding illustration of this is shown by the fact that a baby's weight will ordinarily treble in a year's time. Also we are even more likely to overlook the great quantities of heat energy needed to keep the infant's body warm and supply it with energy for muscular activity Much attention in the last few years has been given to the calorific value of foods as well as the influence of one food upon another during digestion. If the composition of a food is known, its approximate fuel value can be readily and easily determined. From observations of the amount of food consumed (dietary studies) it has been calculated that a man of average size, not engaged in physical labor, requires per day from his food approximately 2500 Calories of energy. Experiments have shown that one gram of fat taken as a food can produce nine Calories of heat, or enough heat to raise the temperature of 9000 grams of water 1°C Fats contain approximately twice as much energy as either carbohydrates or proteins, as is shown below.

The table on page 10 shows the heat values of some foods. As a general rule the contents of numerical tables are not to be memo-

Class of Foods	Calories Per Gram	Calories Per Pound
Carbohydrates	4	1815
Fats	9	4082
Proteins	4	1815
	1	1

rized but are to be examined carefully for facts of general interest and to be used for reference purposes

#### FOOD VALUES

Food	Protein Per Cent	Fat Per Cent	Carbohy drates Per Cent	One Serving in Grams	Total Calories
Bread	91	16	53 3	85	230 0
Butter	10	850		21	169 0
Beef (lean)	190	130		128	250 0
Bacon (smoked)	105	66 0		28	188 6
Eggs	134	105		106	179 0
Milk	33	40	50	170	123 6
Potato (baked)	33	03	22 7	210	245 0
Sugar			100 0	21	81 0

#### SELE-TESTING OUESTIONS

- 6 With what two factors do chemical changes deal?
  - 7 Define matter and energy
- 8 Name several different forms of energy 9 What is potential and kinetic energy?
- 10 What finally becomes of the energy of motion?
- 11 What are the two principal uses of energy produced in the body?
- 12 What is your explanation of the Law of Conservation of Energy?
- 13 Define the unit of heat energy in metric terms
- 14 Define the unit of heat energy in the British system

#### III FIEMENTS AND THEIR OCCURRENCE

#### Elements, the Basic Forms of Matter

In the study of foods and other chemical substances we find that all forms of matter are composed of one or more of 92° simple or elementary substances which are considered as the basic forms of all matter. Sometimes these elementary substances or elements occur in the native or free state (uncombined) other times in a combined state. Thus iron sometimes occurs free in nature but it is found much more often in chemical combination with other elements for example with oxygen as the ore called hematite.

Many of the elements such as gold silver iron and copper are familiar to us since they exist as solids. Ten of the elements are

<sup>\*</sup>Eleven additional elements have been prepared artificially at this writing

gases, and two, mercury and bromine, are liquids at ordinary temperatures.

Of all elements, oxygen is the most abundant, but even so it escaped discovery until 1774, when Priestley, a chemist and minister, first prepared it by heating the red powder, mercuric oxide.



Fig. 5—Joseph Priestley. The discoverer of oxygen. Courtesy, "A Life of Joseph Priestley," Anne Holt (Oxford Press)



The gas evolved upon heating mercuric oxide causes a glowing splint to burst into fiame and is called oxygen During the heating a gray, silvery substance condenses on the inside of the test tube (Fig. 6). This substance is mercury.

Fig 6—Mercuric oxide is readily decomposed by heat How can you prove the presence of the elements, mercury and oxygen, in mercuric oxide?

Neither oxygen nor mercury has yet been decomposed into any simpler form by ordinary means. For this reason these two substances are called *elements* or elementary substances.

These simple substances (elements) are the units or "building blocks" out of which everything is made. Elements, however, may chlorine, is a poisonous gas, yet the compound formed by the union of this element with sodium becomes a most important and valuable food material. In some cases, however, the most easily observable characteristics are the same before and after a chemical change. For instance, when the white solid, potassium chlorate, is heated, oxygen is evolved, and another white compound, potassium chloride, remains A chemical change, however, has occurred. On the other hand, when ice is heated, its most obvious characteristics change. Still no change in chemical composition has taken place.

In the analysis of any sample of sodium chloride (NaCl) one finds that the sodium and chlorine are always present in the same proportion by weight In fact, in all salts and in all compounds, the elements present are united in a definite proportion by weight, i.e., the composition of a compound never veries. Any such established facts are called laws of nature, and this great generalization is known as the Law of Definite Proportion.

## Mixtures, Substances of No Fixed Composition

Elements or compounds may often be mixed together without undergoing any chemical change and such a mixture may have its distinct ingredients present in a varying proportion, as are the ingredients in the soil, in the air, in the foods we eat, and in many medicinal preparations. Even though a mixture may appear to be homogeneous (the same throughout), by various methods it can always be shown that each component has retained its original characteristic properties and may be separated by some mechanical means. Iron powder, for example, can be separated from a mixture of powdered iron and sulfur by means of a magnet, or the sulfur can be dissolved in carbon disulfide, filtered away from the iron and recovered when the carbon disulfide, exponders when the carbon disulfide exponders the man and recovered when the carbon disulfide exponders.

The letters, the combinations of letters to make words, and the mixtures of separate letters and words to make a variety of sen tences in this book illustrate the distinction made in chemistry between elements, compounds, and mixtures

#### Pharmacology Correlation

The importance of chemistry to Materia Medica is apparent when one consults the following partial list of the more important elements with some of their compounds. Note specifically the medicinal uses of these compounds and their action

# SOME IMPORTANT ELEMENTS, THEIR COMPOUNDS AND USES

Element	Compound of	Some Medicinal Uses
Aluminum	Alumnum acetate	Astringent to contract nucous membranes, as a gargle and douche Astringent and antiseptic in surgical dressings
Arsenic	Arsenic trioxide Potassium arsenite	Hematinic, i. e., increases the amount of red corpuscles in the blood, thereby acting as a tonic to improve the ap- petite and digestion
	Arsphenamine	Specific for syphilis
Banum	Barium sulfate	Coats the stomach and intestines for taking x ray pictures
Bismuth	Bismuth submitrate Bismuth subcar bonate	Insoluble compounds used as dusting powders on the skin, astringents and antiseptics for ulcerations of the stomach
Boron	Boric acid (boracic acid)	Mild antiseptic, nonirritating, particu- larly used for an eyewash
Bromine	Sodium and potas sium bromides	Nerve sedatives
Calcium	Calcium chloride Calcium lactate	Assists in clotting of the blood Calcium compounds are used for the treatment of tetany in children Calcium salts are necessary for the growth of bones and teeth, for regulating muscular, nervous, and glandular activity
Chlorine	Sodium chloride Chlorinated lime	Common salt Disinfectant for urinals and excreta A deodorant
Copper	Copper sulfate (blue vitriol)	Removes granulations on the eyelids in trachoma Produces vomiting Used as an astringent
Hydrogen	All acids, e.g., hydro- chloric	Dilute solutions extract water from the tissues, and in the stomach aid digestion.
	Hydrogen peroxide	Antiseptic
Iodine	Iodine tincture Potassium iodide	Antiseptic Treatment of syphilis, to increase secre- tions, and as treatment in hyperthy roldism
	<del>·</del>	<u> </u>

# SOME IMPORTANT ELEMENTS, THEIR COMPOUNDS AND USES (Continued)

Element	Compound of	Some Medicinal Uses		
Iron	Iron chloride	Hematinic as in cases of anemia Astrin		
Lead	Lead acetate	Astringent Contracts tissues in ulcers and wounds		
Magnesium	Magnesium citrate Magnesium hydrox ide (milk of mag nesia)	Purgative Cathartic, neutralizes acidity of the stomach		
		Purgative Allays inflammations		
Mercury	Mercuric chloride (bichloride of mer	Local antiseptic		
	Mercurous chloride	Cathartic		
	(calomel) Mercuric salicylate	Intramuscular injection in syphilis		
Nitrogen	Nitrous oxide (laughing gas)	Anesthetic		
	Ammonia water	Cleanser, heart stimulant		
Oxygen		Used in resuscitation in anoma, and in basal metabolism		
Phosphorus	Sodium phosphate	Saline purgative Reduces accumulation of fluid in the tissues, as in edema		
Pota≪ium	Potassium acetate Potassium perman	Diuretic Antiseptic for wounds		
	ganate Potassium sodium tartrate	Saline purgative		
Radium	Radium bromide	Treatment for cancer		
Silver	Silver nitrate	Antiseptic to contract mucous mem branes of eye, to cauterize, and for nose and throat inflammations		
Sodium	Sodium bicarbonate (baking soda)	Acidosis treatment		
Sulfur	tonning south)	Used in continents for skin diseases. May be used as a laxative		
Zinc	Zinc oxide Zinc stearate Zinc sulfate	Astringent Dusting powder (urntating if inhaled) Produces vomiting		

#### SELE-TESTING QUESTIONS

- 18 How many elements are there?
- 19 Define a compound, and give several examples
- 20 What is the Law of Definite Composition? Explain it
- 21 How does a mixture differ from a compound?

#### SUGGESTED ACTIVITIES

#### I THOUGHT PROVOKING QUESTIONS

- 1 Besides a change in composition what is another evidence of chemical change?
- 2 When a candle burns is the matter being destroyed? Explain
- 3 Name several elements found in the body and state why they are important
- 4 By what ways can you distinguish between a compound and a mixture?
- 5 Do the following produce physical or chemical changes Dressing, breating, eating, melting butter, souring of milk, decay of leaves, freezing of water, the formation of the crust on bread during baking, bandaging a wound?
- 6 Give five examples of chemical changes
- 7 In which of the three groups—elements, compounds or mixtures—does each of the following belong aluminum, milk soap, river water, ice cream face powder?
- 8 Why are we more familiar with iron than with silicon when silicon is much more abundant?
- 9 Calculate the approximate weight of iron in your body
- 10 Are most of the changes that occur in cooking, physical or chemical?
- 11 What characteristics differentiate the element from the compound?
- 12 Make a list of correlations between Chemistry and other nursing subjects, and give examples

#### II VOCABULARY TESTING OF NEW TERMS

The chemical words used in this and the following chapters are especially important to understand because you will be using them repeatedly in expressing your thoughts as you think in terms of chemistry chemical chapter. Kinetic energy metal

chemical change chemical analysis chemical synthesis matter energy kinetic energy chemical energy conservation of energy calorie calorimeter element

nonmetal compound definite composition mixture

potential energy element

- III TOPICS FOR ORAL OR WRITTEN REPORTS
  - 1 Phlogiston Theory
  - 2 Philosopher s Stone

- 3 Discovery of Elements
- 4 Meaning of Names of Elements
- 5 The Calonfic Value of Foods
- 6 Energy Requirements of the Body
- 7 Percentage of Elements in the Human Body

#### LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on pages 640 642

# ATOMS, MOLECULES, AND THE ELECTRON THEORY

#### CHAPTER OUTLINE

- I ATOMIC THEORY
  (a) Molecules
  - (b) Atoms
  - (c) The atomic theory
  - (d) Atomic weight
  - (e) Symbols
  - (f) Formulas
- II ELECTRON THEORY
  (a) Structure of atoms
  - (b) Picturing the atom (c) Isotopes
- III VALENCE
  (a) Meaning of valence

- (b) Metals and nonmetals, chem
  - ical activity
    (c) Valence of radicals
- IV FORMULA WRITING
  (a) Using valence to make
  - formulas (b) Structural formulas
  - (c) Practice in formula writing
  - V Equation Writing
    (a) Meaning of equations
    - (a) Meaning of equations
      (b) Balancing a chemical equation
      (c) Practice in goustion writing
- I. ATOMIC THEORY

# Molecules, the Physical or Structural Units of Matter:

We know that most substances, iron, for example, expand when heated and contract when cooled, but that the weight of the substance does not change even though its volume has altered. Again, if we make a mixture of 50 ml of alcohol and 50 ml of water, we will have less than 100 ml. of the solution (Fig. 1). This smaller

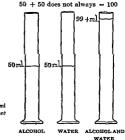


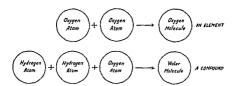
Fig. 1.—The mixture will not total 100 ml because of intermolecular displacement Will this be true for all liquid mixtures<sup>2</sup>

combined volume is explained by saying that some of the particles of alcohol occupy spaces between particles of water, a condition which may be compared with the fact that one bushel of potatoes and one bushel of wheat, when mixed, do not fill a two bushel measure From these and similar observations we may conclude that there are spaces between the particles of substances, not only between the particles of compounds, but also between the particles of elements. In the case of the element iron, the expansion in vol ume, due to the rise in temperature, means that the spaces between the particles of the iron have increased in size. These particles are in motion at all times and thus occupy a larger space when heated The smallest of these conceivable particles of matter (either elements or compounds) that can exist, take part in chemical reactions, and still be recognized as the original substances are called "molecules" Molecules of the same particular substance are supposed to be alike in every respect

From the foregoing statements it is evident that molecules are invisible particles which make up matter, and that the properties of matter are in reality the properties of the aggregate molecules

#### Atoms, the Chemical or Basic Structural Units of Elements

Imagine that a single molecule of water  $(H_2O)$  is further divided No longer will we have a molecule of water with all of its character istic properties, but instead particles of hydrogen and oxygen from which the water molecule is constructed. These particles are atoms. Atoms rarely exist singly, but are almost always found in chemical combination with one another to form molecules. Molecules are sometimes the same particles as atoms e g, atoms of ecules are sometimes the same particles as atoms e g, atoms of



F.g. 2--Difference Between a Gaseous Element and a Compound. How does the composition of a molecule of a gaseous element differ from that of a compound?

iron are identical with molecules of iron. Hence the iron molecule is monatomic

Most metallic elements are like iron in that their molecules consist of but one atom. On the other hand, some of the active non-metallic elements, as oxygen and hydrogen, contain two atoms in each molecule, while other nonmetals, like phosphorus and arsenic, have even more atoms per molecule. Compounds like water (H<sub>2</sub>O), which are made up of different kinds of atoms, are also referred to as molecules. Hence there are elementary molecules, for example O<sub>2</sub>, and compound molecules, for example H<sub>2</sub>O (Fig. 2) Molecules usually are larger than atoms and are composed of atoms. The smallest ordinarily\* indivisible part of an element is an atom.

All atoms of the same element are alike in their chemical properties. When chemical changes occur between elements or compounds, it is between the atoms which constitute the reacting molecules. The properties of the resulting molecules are due to the separating, the rearranging, and the recombining of the atoms. The change is comparable to the tearing down of a building, separating the materials, and rearranging and combining these materials to form a new building with entirely new properties.

As has been stated, each molecule of an active gaseous element is made up of at least two atoms held together in chemical combina tion. In the case of compounds, as water, H<sub>2</sub>O, two hydrogen atoms and one oxygen atom unite to form a molecule, and any amount of water is simply a collection of a definite number of these water molecules.

## The Atomic Theory:

In order to explain certain observed facts about chemical reactions, John Dalton, an Englishman, about 1807 formulated an atomic theory. This theory has never been replaced by a better one, but certain changes have been found necessary to keep it up to date. Some of these modifications in the theory will be discussed later. In brief, the original Dalton's atomic theory proposed.

- Chemical elements are made up of indivisible particles of matter called atoms
- 2 All atoms of a given element are alike in physical and chemical properties

<sup>\*</sup> It should be stated that certain substances called radoactive elements decompose spontaneously into other elements and that also by means of the cyclotron and other special machines nuclear changes in stome can be brought about. The dream of the alchemists that is artificial transmutation of the elements has at long last been realized.

Atoms combine chemically in small whole-number ratios to form molecules.

Dalton's atomic theory has served as a cornerstone in the development of chemistry.

# Atomic Weights:

Atoms are so small that it is obviously impossible to weigh them individually. However, it is possible to weigh groups of atoms. each group containing the same number, and in this way to determine the relative weights of atoms in terms of a suitable reference standard. A carbon atom is taken as the standard for comparison. and assigned the value of exactly 12,000. This then makes the hydrogen atom, the lightest of all atoms, have a relative weight slightly greater than unity (1.00797). Scientists only recently changed over to carbon-12 (C12) as the reference standard The C12 atom is the most abundant isotope of carbon (see page 27). The new atomic weight values, based on C12, differ very little from those previously based on oxygen as exactly 16 000, since the two scales differ by only 37 parts in one million. On the new scale the atomic weight of oxygen becomes 15.9994. By making this change both chemists and physicists now have identical atomic weight scales

Notice that the atomic weight of any element is the number which expresses the ratio of the weight of an atom of that element to one-twelfth the weight of the reference carbon atom. Atomic weights are relative weights, For example, the helium atom is

SOME IMPORTANT ELEMENTS, THEIR SYMBOLS AND ATOMIC WEIGHTS
BASED ON CARRON—17

Element	Symbol	Atomic Wt	Element	Symbol	Atomic Wt
Aluminum	Al	26 9815	Magnesium	Mg	24 312
Bismuth	Bı	208 980	Mercury	Hg	200 59
Bromine	Br	79 909	Nitrogen	N	14 0067
Calcium .	Ca	40 08	Oxygen, ,	(σ	15 9994
Chlorine	C1	35.453	Phosphorus	P	30 9738
Copper	Cu	63 54	Potassium	K	39 102
Hydrogen .	н	1 00797	Silver	Ag	107 870
Iodine	1	126 904	Sodium	Na	22 9898
Iron	Fe	55 847	Sulfur,	s	32 064
Lead	Pь	207 19	Tin	Sn	118 69

approximately one-third as heavy as the reference carbon atom, and hence the atomic weight of helium is about 4.

Atomic weights of some of the more common and important elements are given in the table (p. 22). For the usual calculations requiring atomic weights it is permissible to approximate the values to the first place after the decimal.

### Symbols, Abbreviations for Elements:

Instead of writing out the names of elements it is often more convenient to use abbreviations. These abbreviations, called symbols, are usually the first letter or letters of the names of the elements, as H for hydrogen, O for oxygen, C for carbon, Ca for calcium, etc. To indicate more than one atom of the same kind write the proper figure in front of the symbol; thus 3 H represents three atoms of hydrogen. If, however, the atoms referred to form part of a molecule, then the number is written as a subscript, e.g., Hz represents two such molecules. All chemically active gaseous elements, when occurring alone, should be written to indicate their molecular condition, e.g., Hs for hydrogen, and Clf for chlorine.

The symbol should also be remembered as representing not only an atom of the element, but also a definite weight, which, when expressed in grams, is called the "gram-atomic weight" of the element. For example, the hydrogen atom weighs 1.00797, and the oxygen atom weighs 15.9994. The symbol H then means 1.00797 grams of hydrogen, and the symbol O means 15.9994 grams of oxygen. Refer to page 631 for the names of the elements, their symbols, valences, and atomic weights.

### Formulas: Abbreviations for Compounds:

By the use of symbols we may represent the composition of a compound by indicating the number and the variety of atoms that make up its molecules, e. g., H<sub>2</sub>O represents one molecule of the compound, water, composed of two atoms of hydrogen and one of oxygen. Such an arrangement of symbols in representing a molecule is called the formula of that compound. In addition to telling at a glance what kind of atoms, and how many of them make up a molecule of a compound, the formula frequently informs us of the nature of the compound, and how it will be expected to behave. For instance, all acids are hydrogen compounds and the formula HCI not only shows the composition of the molecule, but also in this case

#### SOME IMPORTANT FORMULAS

Hydrochloric acid	}HCI	Calcium hydroxide	Ca(OH) 2
Hydrogen chloride	ACI	Sodium hydroxide	NaOH
Sulfuric acid	H2SO4	Magnesium sulfate	MgSO <sub>4</sub>
Hydrogen sulfate	112004	Mercuric chloride	HgCl <sub>2</sub>
Carbonic acid	H2CO3	Potassium iodide	KI
Hydrogen carbonate	H2003	Potassium nitrate	KNO <sub>3</sub>
Phosphoric acid	HaPO.	Sodium bicarbonate	NaHCO <sub>a</sub>
Hydrogen phosphate	H <sub>3</sub> PO <sub>4</sub>	Sodium carbonate	Na <sub>2</sub> CO <sub>3</sub>
Nitric acid	HNO.	Sodium chloride	NaCl
Hydrogen nitrate	HNO <sub>3</sub>	Silver nitrate	AgNO <sub>3</sub>

suggests the additional facts that it is an acid, will taste sour, and will show other characteristic properties of an acid. A formula also stands for a molecule of an element. For example, the formula for oxygen is O2, showing that the oxygen molecule contains two atoms of oxygen

A formula can also be used to represent a definite weight of a compound which, if expressed in grams, becomes the gram formula weight For example the gram formula weight of water (H2O) is 18 01534 grams. For most uses the value 18 0 is sufficient

### SELE-TESTING OUESTIONS

- Define and give an example of a molecule
- 2 What is an atom?
- 3 How may the composition of a molecule of a metal differ from that of a nonmetal?
- 4 What is meant by atomic weight?
- 5 Define and give an example of a symbol
- 6 What information does a formula convey?

#### II. ELECTRON THEORY

During this present century there has been developed a theory called the electron theory, which explains the structure of the atom from an electrical standpoint. This new theory does not in any way overthrow former ideas as to the chemical union of atoms. It merely adds to older ideas, and clarifies what takes place in a chemical change

#### Structure of Atoms

According to the electron theory, the atom of every element (except ordinary hydrogen) is composed of positive electrical units called protons, negative electrical particles called electrons, and

neutral particles called neutrons. In any atom the number of electrons is equal to the number of protons, that is to say, under ordinary conditions the atom is electrically neutral. An electron is a very light particle, about 1/1845 of the weight of a hydrogen atom, the lightest of all atoms In fact, the mass of the electron is so nearly zero that usually it is not considered in determining the total mass of an atom On the other hand, the proton is heavier, and is approximately the mass of the hydrogen atom Research has also shown the presence of a third kind of particle in the atoms of all elements excepting hydrogen. This third particle, called the neutron, is electrically neutral and has a mass nearly the same as the proton Still other particles formed during "smashing" of atoms have been identified, but, for our purposes, discussion will be limited to the proton, electron, and neutron Of these three differ ent kinds of particles the free protons and the neutrons of an atom exist as a small dense mass in the nucleus, while the light electrons are far distant outside the nucleus, and revolve around the nucleus in various orbits much as the nine planets revolve around the sun

Along with these discoveries there has been found a way to express the electrical charge of the nucleus of each of the various kinds of atoms. This electrical charge is called the atomic number and corresponds to the number of free protons (+ charges) in the nucleus or to the number of electrons (- charges) in the shells around the nucleus.

# Picturing the Atom.

By means of the atomic number and the atomic weight (page 631) for each atom it now is possible to formulate some kind of a picture showing the differences in the structures of the various kinds of atoms

Hydrogen the lightest of all elements, has the simplest atomic structure since its atomic number is 1. The ordinary hydrogen atom contains just one proton and one electron (Fig. 3). There can be no neutron in its nucleus because the atomic weight of one agrees so closely with the weight of a proton

The next simplest atom is belium with an atomic number of 2, and an atomic weight of 4 This atom, therefore, must contain two protons and two neutrons (symbol n) in its nucleus, and two electrons revolving outside of the nucleus (Fig 4) This completes the number of electrons possible in the first shell or energy level outside the nucleus of any atom

The lithium atom with an atomic number of 3, and an atomic



Fig. 3—Hyd ogen atom showing one efection rotating around one pioton

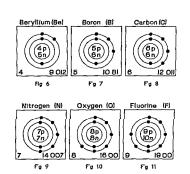


Fg 4—Helum an Inac t ve element since its shell is complete



Fig 5—Lithum an active element containing one electron in its outer shell

weight of approximately 7, contains three protons and four neutrons in its nucleus and three electrons revolving outside the nucleus but since not more than two electrons can revolve in the first shell the third electron revolves in a second shell at still a greater distance from the nucleus (Fig 5). This second shell being larger, can hold as many as eight electrons before it is complete as may be noted by studying the structures of the seven elements (Figs 6 to 12).



The above d agrams illustrate the concept on of the structure of the atoms

Additional protons, with a corresponding increase in electrons, and an increase in neutrons, form combinations to give still heavier atoms. With successive elements the third shell builds up to eight electrons before a fourth shell is started. However, eventually with heavier atoms, the third shell builds to a maximum of eighteen electrons. The fourth shell may become stabilized with the number



Fig 12—Neon an inactive element with its electronic shell complete

8, 18, or 32, depending upon the mass of the atom. The element radium with its atomic number of 88 divides its electrons into consecutive shells as follows 2, 8, 18, 32, 18, 8, 2

# Isotopes, Atoms of an Element Differing in Atomic Weight:

The mass of the electron is negligible when compared with the mass of the proton or the neutron Since the mass of an atom depends almost entirely upon the number of nuclear protons and neutrons, each having essentially unit mass, it would seem that the atomic weight of any element should be a whole number A glance, however, at the table of atomic weights shows that most atomic weights cannot be expressed by whole numbers Lithium for example (Fig 13) with an atomic weight of 6 940 has two kinds of atoms Both have an atomic number of 3, but one kind of atom has a mass of 6 (3 protons plus 3 neutrons), while the other kind has a mass of 7 (3 protons plus 4 neutrons) Ordinary lithium has both kinds of atoms, and consequently the atomic weight 6 940 represents a weighted average of the two different





Fig. 13-The two isotopes of lithlum.

kinds of lithium atoms as they occur in natural lithium \* They differ only in the number of neutrons in the nucleus, and since both kinds of atoms have the same atomic number they are alike chemically These different forms of atoms of the same element, alike in most every respect except mass, are called isotopes

#### SELF-TESTING QUESTIONS

- 7 What is the composition of an atom?
- 8 How can you distinguish between a proton an electron and a neutron?
  9 How are the protons and electrons grouped in an atom? The neutrons?
- 10 What is the atomic number of an atom?
- 11 What are isotopes?

# III. VALENCE

### Meaning of Valence:

A study of the formulas of the following compounds

HCI	H₂O	NH <sub>3</sub>	CH₄
Hydrogen	Water	Ammonia	Methane

reveals the fact that different kinds of atoms are able to hold different numbers of hydrogen atoms in combination. Recall that each hydrogen atom contains one electron in its shell. The number of hydrogen atoms that will combine with (or replace) one atom of a given element is called the valence of that element. Thus, in the previous formulas, chlorine (Cl) has a valence of one, oxygen (O) a valence of two, nitregen (N) of three, and carbon (C) of four. With the understanding of the established valence (combining power) of chlorine (1), of oxygen (2), introgen (3), and carbon (4) it is not difficult to reason that the valence of Fe in FeCl<sub>3</sub> is three, of Ca in CaO is two, of nitrogen in NoO<sub>3</sub> is three, and of S in SiC is four.

A theory has been worked out which explains valence in terms of the electrons in the outer shell of the atom. In brief, the theory proposes (a) The valence of an element is equal to the number of electrons which an atom of that element must lose, gain, or share in order to realize a stable outer shell of electrons (b) When atoms attain stability by loss or gain of electrons they become charged particles, called ions. The ions are then held together by electrical forces. The structure which results is an ionic compound, and the type of valence is called electrovalence, or ionic bonding. (c) Some atoms in their reactions gain stability for the outer shell by a

<sup>\*</sup>In Figs 3 through 12 the atomic weights given are for the elements in their natural occurrence and hence may express mixtures of isotopes.

process of sharing electrons. This results in a type of valence or combining capacity termed covalence, and the compound which is produced is a molecular compound.

To illustrate the theory for formation of ionic compounds sodium chloride (salt) will serve as an example. The sodium atom has two electrons in its first shell, eight in its second shell, but only one in its third and outer shell (Fig. 14). The sodium atom may thus attain

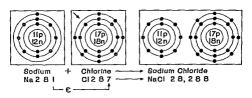


Fig 14—Chemical change in terms of planetary electrons

a stable outer shell by losing the one outer electron Chlorine, on the other hand has seven electrons in its outer shell, so that if it should gain one electron, it would have a stable outer shell of eight. In sodium chloride, the sodium atom has given its electron to the chlorine atom so that both now have stable outer shells, and the resulting positive electric charge on the sodium atom, now called the sodium ion, and the negative electric charge on the chlorine atom, now called the chloride ion, bind the two together. When an atom has few electrons in its outer shell, it will tend to lose these electrons and is said to have a positive valence. Sodium, for exam ple, has a positive valence of one. When an atom his chlorine has an almost complete outer shell, it will tend to gain electrons, and it is then said to have a negative valence. This type of valence, called electrovalence, which is due to actual loss and gain of electrons, is typical of many of the saits and metal oxides.

As already stated, certain atoms in their reactions may gain stability by the sharing of electrons. The chlorine molecule (Cl<sub>2</sub>) is of this nature. Each chlorine atom has seven outer shell (valence) electrons. In the structure for the chlorine molecule (Fig. 15), notice that two of the outer shell electrons are placed between the nuclei in such a manner that they are associated with both nuclei and as a consequence each chlorine atom in this structure has the

stable number of eight electrons in its outermost shell. Notice that this has become possible by the sharing of two electrons, each atom contributing one for this purpose, hence these two electrons are the common property of both atoms. Since no electrons have been lost or gained by the chlorine atoms in arriving at the structure of the chlorine molecule, there are no ions present. Chlorine molecules are true molecular structures. The type of valence which arises from the sharing of electrons is covalence.





Many compounds are molecular in character This includes not only numerous inorganic compounds, but also practically all organic compounds The covalent type of bonding will be discussed later in more detail

In summary, the following statements about the two types of valence are presented

For ionic compounds

- (a) When stability of structure is attained by the loss and gain of electrons on the part of reacting atoms ionic compounds are produced.
- (b) The ion is a charged particle which has resulted from an atom gaining or losing one or more electrons in reacting
- (c) The building units in the ionic type of compound are ions. In most cases ionic compounds are solid salts and metal oxides in which the ions have a definite geometrical pattern of arrangement.
- (d) The valence of an element which forms ionic compounds is equal to the number of electrons lost or gained by an atom of the element Positive valence numbers are due to loss of electrons, and negative valence numbers are the result of a gain of electrons. Such valence, a characteristic of all ionic compounds is electrovalence.

#### For molecular compounds

(a) In molecular compounds, stability of structure has been attained by the sharing of electrons on the part of the atoms involved

- (b) In molecular compounds the molecule itself becomes the structural unit Thus a given quantity of water is a collection of water molecules
- (c) The valence of an element in a molecular compound is equal to the number of electrons which an atom of the element provides for sharing purposes. Often the valence numbers in molecular compounds are not represented by plus or minus inasmuch as no ions are present. This type of valence, which is characteristic of the atoms in true molecules, is covalence.

### Metals and Nonmetals; Chemical Activity.

Elements like sodium and calcium, which readily lose electrons, are generally solids, have a metallic luster, and are good conductors of heat and electricity. On the other hand, a number of the elements readily pick up electrons and do not have these physical properties.

The electron theory provides another way of classifying elements into metals and nonmetals. The metals are those elements that lose or tend to lose electrons in reacting and hence become electropositive, while the nonmetals are the elements which gain or tend to gain electrons and become electronegative. Certain elements have no pronounced tendency to gain or to lose electrons, and may behave either as nonmetals or metals, depending upon conditions of reaction. These are frequently called amphotenc elements. Those elements whose atoms tend to share electrons in reacting are usually viewed as nonmetals because the various atoms involved in the structure of the molecule become associated with a greater number of electrons.

Certain atoms in some cases may find it possible to lose only a part of the number of electrons which should be lost for ideal stability. Others may find that not all electrons needed for stability can be acquired, because of conditions of reaction. In such cases variable valence will be the result, however, every element has one valence that usually predominates. Copper, for example, has two valences, namely one and two, its valence of two is the more important.

Those elements whose atoms already have completed outer shells are inactive chemically, they cannot gain, lose or share electrons. Thus helium and neon (Figs. 4 and 12) with completed outer shells are chemically mert and form no stable compounds.

#### Valence of Radicals:

Frequently in life, groups of people cling together and act as a unit or part of a larger unit. So, in chemistry, associations composed of groups of atoms cling together, act as a unit, and have a definite valence. These groups of atoms are called radicals and have special names. For example, in the formula H2SO4, the one unit (SO4), called the sulfate radical, is combined with two atoms of hydrogen, and the valence is therefore two, or it is said to be divalent. If more than one of the radicals is used in making a formula, then the radical must be placed in parentheses and a subscript added, the subscript indicating that all of the atoms within the parentheses are to be taken a specified number of times. Thus, in the formula Al2(SO4)3, three sulfate radicals are combined with two aluminum atoms. A radical is not a definite compound any more than the group of letters "ing" in "reducing" is a definite word; nevertheless, these groups of elements are essential in forming some compounds. Furthermore, in reactions in solutions, these radicals of the compounds usually remain unchanged as they move from one compound to another

#### VALENCES OF SOME COMMON ELEMENTS AND RADICALS

Element or Radical	Symbol	Valence	Element or Radical	Symbol	Valence
Hydrogen .	H	+1	Tin		
Sodium	Na	+1	Stannous	Sn	+2
Potassium	K	+1	Stannic .	Sn	+4
Silver	Ag	] +1 ]	Aluminum	A1	+3
Barium	Ba	+2	Bismuth	Bı	+3
Magnesium	Mg	+2	Ammonium	NH4	+1
Calcium	Ca	+2	Chlorine	CI	-1
Zine	Zn	+2	Bromine	Br	-1
Lead	Pb	+2	Iodine	1	-1
Copper	1	1 1	Oxygen	0	-2
Cuprous	Cu	+1	Sulfur	S	-2, +4, +6
Cupric	Cu	+2	Phosphorus	P	-3, +3, +5
Mercury	}	, ,	Nitrogen	N	-3, +3 to +t
Mercurous	Hg	+1	Carbon	c	-4
Mercuric	Hg	+2	Hydroxyl	OH	1
Iron	I		Nitrate	NO <sub>3</sub>	-1
Ferrous .	Fe	+2	Bicarbonate	HCO <sub>3</sub>	-1
Ferric	Fe	+3	Sulfate.	SO.	-2
	)	, J	Carbonate	CO <sub>3</sub>	-2
	ł	l i	Phosphate	PO4	-3

The names, formulas, and valences of some of the more common elements and radicals are listed on p 32

#### SELF-TESTING QUESTIONS

- 12 What is meant by valence?
- 13 What determines whether an element has a positive or a negative valence?
- 14 What are the two kinds of valence and to what is each due? 15 How does an ionic compound differ from a molecular compound?
- 16 What determines the activity of an element?
- 17 What is meant by a radical?
- 18 When the outer shell is complete is the element ordinarily active?

#### IV. FORMULA WRITING

# Using Valence to Make Formulas.

Sometimes it is necessary to make formulas for the compounds with which we are working With an understanding of the meaning of valence and knowing the valences of elements and radicals, it is not difficult to write the formulas of most compounds. It should be kept in mind that the sum total of the valences of the positive elements or radicals must equal the sum of the valences of the negative elements or radicals in any compound

Suppose that you wish to write the formula of calcium chloride Then follow this procedure

- 1 Write the symbols for the atoms in the compound, the positive acting atom being written to the left CaCl
- 2 Mark the valences of the atoms above and to the right of their symbols (When the compound is ionic, we generally do this by using as many plus or minus marks as equals the valence of the element or radical in the reaction and we use the sign that corre sponds to the charge carried by the elements or radical in the particular reaction ) Ca++CI
- 3 Find the least common multiple of the valences of the atoms or radicals (two in this example)
- 4 Divide the least common multiple by the valences of the two different atoms or radicals and use the numbers obtained as subscripts to indicate the ratio between the number of atoms in the compound

compound 
$$C_{\alpha^{++}}$$
  $C_{1^{-}}$   $(2-2=1)$   $(2-1=2)$  giving  $C_{\alpha}Cl_{2}$ 

When the subscript is one (1), it is omitted and so whenever no subscript appears, it is understood to be one

Notice that the number of atoms used is such as to give an equal number of positive and negative valences

The same method is used in making formulas with radicals, but a parenthesis is necessary when the compound radical is present more than once

$$C_{q^{++}}$$
  $(PO_{4})^{---}$   
 $(6 - 2 = 3)$   $(6 \div 3 = 2)$   
 $C_{\alpha_{3}}(PO_{4})_{2}$ 

An easy rule of thumb procedure for writing formulas is to "criss cross" valence numbers where odd and even valences are concerned



Sometimes an element may have more than one valence, that is, have a certain valence in one compound and a different valence in another Whenever an element has two or more valences, the higher valences are usually represented by "ic" and the lower by "ous" in the names of its compounds For example, HgCl<sub>2</sub> in which mercury has a valence of two is mercuric chloride and HgCl<sub>3</sub> or Hg-Cl<sub>3</sub>, in which mercury as a valence of one is mercurous chloride while FeCl<sub>3</sub> is ferric chloride and FeCl<sub>2</sub> is ferrous chloride. A newer practice which is gaining in favor is to write mercury (II) chloride, mercury (I) chloride, etc., the Roman numeral in the parentheses showing the valence

In some instances, such as in the case of  $H_2O_2$ , and  $Fe_3O_4$ , an element may have an unusual or even an apparently fractional valence, for reasons we need not consider

### Structural or Graphic Formulas

Sometimes it is clearer to represent the valence by the use of a short line or a "bond" between the atoms. This provides a graphic representation of the arrangement of the atoms of elements in the molecules of compounds.

A study of the table on page 35 will illustrate structural formula writing

Structural formula writing as a method of representing the relation of atoms to each other will become more apparent in the organic and biochemical discussions

## Practice in Formula Writing

Making correct formulas for substances entering into a chemical change is so important that the chart on page 36 is inserted for practice. Combine each element or radical in the vertical column with

Elements	Valence	Formula	Structural Formula	Name of Compound
Hydrogen Chlorine	1	нсі	H—Cl	Hydrogen chloride
Hydrogen Oxygen	1 2	H₂O	Н	Water
Hydrogen Nitrogen	1 3	NH <sub>8</sub>	N—H	Ammonia
Hydrogen Carbon	1 4	СН4	H H H	Methane (marsh gas
Carbon Oxygen	4 2	CO <sub>2</sub>	0          	Carbon dioxide
Nitrogen Oxygen	3 2	N2O3	N=0 0 N=0	Nitrogen trioxide

each element or radical in the horizontal column Omit the squares in which an X appears

#### SELF-TESTING QUESTIONS

- 19 How can a simple formula of a compound be made by the least common multiple method?
- 20 When an element has two or more valences how are they represented in the names of its compounds?
- 21 What is meant by a structural formula?

	Chlo- ride, Cl-	Ox ide, O=	Sul- fate, SO <sub>4</sub> =	Nı traie, NO <sub>3</sub> -	Car- bon ate COs≈	Hy drox ide OH-	Sul fide S-	Phos phate, PO
H+ Hydrogen	HC1							
Ca++ Calcium	_							
Na+ Sodium								
Al+++ Aluminum		_			×			
NH4+ Ammonium		×						
Ag+ Silver						×		
Fe+++ Ferric					×		×	
Hg+ Mercurous						×		
Zn++ Zinc								
Mg++ Magnesium								

# V. FOLIATION WRITING

So far we have used the chemist's shorthand for writing the names of elements and compounds Now we should go a step further and show how he denotes chemical changes, in a very brief way

### Meaning of Equations

With the help of symbols and formulas we can describe any chemical reaction by means of an equation. An equation, then, is simply a shorthand way of expressing a chemical reaction. The symbols and formulas of all materials undergoing change are placed on the left of the arrow, while the products formed are placed on the right The arrow itself means "changes into," "yields," or "forms" For example, the union of iron and sulfur is expressed thus

Word equation: Equation with symbols and formulas

blus Sulfur yields from sulfide

# Balancing a Chemical Equation

The mechanical features of simple equation writing require two steps

1 Write the correct formulas for the reacting substance or sub stances and the product or products formed This might be called a skeleton equation For example, in writing the equation to show what takes place when mercuric oxide is heated, write the correct formulas as follows

2 Balance the equation by prefixing such coefficients to sub stances as will make the same number and kind of atoms on each side of the arrow, but under no consideration change a formula to make the atoms balance

In forming compounds, keep in mind that the positive element or radical of one compound always unites with the negative element or radical of the second compound, and that the positive part of a compound is written first in the formula. Thus in the equation

# Calcium hydroxide + Hydrogen chloride → ?

the positive calcium unites with the negative chlorine and the hydrogen unites with the hydroxide radical Thus we have

The gaseous elements must always be indicated in the molecular state, e.g., H2, O2, Cl2, N2, etc.

$$4 \text{ Na} + O_2 \rightarrow 2 \text{Na}_2 \text{O}$$

Before attempting to write equations it should be pointed out that there is no one way of writing all chemical equations. Every one has to learn by practice the easiest way to write balanced equations for each particular type of reaction. Moreover, since the course of a chemical change cannot always be predicted it must be understood that the chemical equation is an expression of experimental facts, and as such it cannot be altered.

# Practice in Equation Writing:

Follow the two rules and find out whether you can write the correct formulas and balance the equations for the following reactions

- 1 Iron + Sulfur -+ (use ferrous valence)
- 2 Carbon + Oxygen →
- 3 Phosphorus + Ozygen (use phosphorous valence)
- 4 Zinc + Hydrogen chloride → (hydrogen liberated as gas)
- 5 Sodium hydroxide + Hydrogen chloride -
- 6 Silver nitrate + Sodium chloride →
- 7 Magnesium hydroxide + Hydrogen chloride →
- 8 Ammonium hydroxide + Hydrogen sulfate -9 Magnesium chloride + Potassium carbonate--
- 9 Magnesium chioride + Potassium carbonate
  10. Calcium hydroxide + Hydrogen carbonate →
- 11 Sodium chloride + Hydrogen sulfate →
- 12 Ferric chloride + Sodium hydroxide →
- 13 Aluminum oxide + Hydrogen chloride →
- 14 Mercurous nitrate + Ammonium chloride →
- 15 Sodium sulfide + Mercuric chloride →
- 16 Calcium hydroxide + Hydrogen phosphate →
- 17 Ferrous nitrate + Ammonium sulfide →
- 18 Zinc carbonate + Hydrogen phosphate -
- 19 Copper sulfate + Ammonium hydroxide → (use cupric valence)
- 20 Aluminum sulfate + Sodium carbonate →

#### SELF-TESTING QUESTIONS

- 22 What does an equation show?
- 23 What two steps are followed in writing a chemical equation?
- 24 Why must you never change a formula to make atoms balance?
- 25 How are active geseous elements written?

# SUGGESTED ACTIVITIES

- I THOUGHT PROVOKING QUESTIONS
  - 1 When is a chemical change completed?
  - 2 Why are some elements more active than others?
  - 3 What part of an atom determines the activity of an element?
  - 4 What are the valences of the positive elements in the following compounds HgCl, HgCl<sub>2</sub>, ZnSO<sub>4</sub>, Na<sub>2</sub>CO<sub>5</sub>, Fe<sub>2</sub>O<sub>5</sub>, AgNO<sub>5</sub>, MgO, Ca(HCO<sub>2</sub>)<sub>2</sub>?
  - 5 When is a formula written without subscripts?
  - 6 When do certain elements have a zero valence?
  - 7 What should be known before a chemical equation is written?
  - 8 When an equation will not balance, what should be the first thing checked?
  - 9 Why may coefficients, but not subscripts be changed while bal ancing an equation?

- 10 Which of these equations are unbalanced or incorrectly written?
  - (a) Zn + 2HCl → ZnCl2 + 2H
  - (b) 2KClO<sub>3</sub> -heat -> 2KCl + 2O<sub>3</sub>
  - (c)  $2Zn + O_2 \rightarrow 2ZnO$ (d)  $Mg_3 + N_2 \rightarrow Mg_3N_2$
  - (d) Mg<sub>3</sub> + N<sub>2</sub> → Mg<sub>3</sub>N<sub>2</sub>
     (e) CuO + 2H → Cu + H<sub>2</sub>O
- 11 What does the formula of a compound stand for?
- 12 Make a diagram of the calcium atom, considering it to have an atomic number of 20 and an atomic weight of 40
- 13 How do you account for the fact that the atom of heavy hydrogen (deuterium) has an atomic weight of 2?
  - 14 What is meant by a 'weighted average ?
- 15 In what ways has the original Dalton s atomic theory been modified?
- II Vocabulary Testing of New Terms

molecule atom atomic weight symbol	formula atomic number proton electron	valence electrons valence metal nonmetal	amphoteric radical structural formula variable valence

- III TOPICS FOR ORAL OR WRITTEN REPORTS
  - 1 The Electron Theory
  - 2 Within the Atom—Atomic Structure
  - 3 Why Formulas and Equations Have Value
  - 4 The Change to Carbon 12 for Relative Atomic Weights

#### LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on pages 644, 646, 648

## OXYGEN-THE LIFE-SUPPORTING ELEMENT

### CHAPTER OUTLINE

- I IMPORTANCE AND ABUNDANCE
  - (a) Importance
  - (b) Abundance
- II PREPARATION AND PROPERTIES.
  - (a) Preparation (b) Properties
  - (c) Oxides
  - (d) Oxygenation
  - (e) Oxygenating agents
  - (f) Combustion
  - (g) Oxidation and combustion (h) Oxidation and reduction from
  - the electronic view
    (i) Spontaneous combustion
    (i) Another form of oxygen
  - (k) Uses of ozone

- III FIRES
  - (a) Matches (b) Fireproof materials
  - (c) Fire extinguishers
- IV Uses of Oxygen (a) Oxygen in nature
  - (b) Oxygen in industry (c) Oxygen in medical practice
  - (c) Oxygen in medical pract: (d) Air conditioning
  - V PHYSIOLOGICAL CORRELATIONS
    (a) Respiration
  - (1) Oxygen in breathing
    - (2) Oxygen in medicine (b) Oxygen requirement
  - (c) Symptoms of anoxemia (d) Guide for oxygen therapy



Fig 1—Infant Incubator New techniques in obstetrics and pediatrics have been major factors in lengthening the life expectancy of the children born today. In what other ways has chemistry contributed to an advance in life expectancy? Courtery, New York Life Insurance Company.

# I. IMPORTANCE AND ABUNDANCE OF OXYGEN

## importance:

It is difficult to realize just how much we depend upon the free oxygen of the air. Every breath of life consumes some of this gas. Man can live without water for a few days and without food for weeks, but lack of oxygen, the most fundamental requisite for maintenance of life, is fatal within a few minutes. Not an animal and searcely a plant can live without it, and a fire cannot be started without it to produce heat and light. Oxygen is the one element that is essential in bringing about, through chemical changes, the conversion of the chemical energy of foods and tissues into heat and mechanical energy, the latter being used in producing body movement and activity of the organs and tissues. Only a small part of the food eaten is used to repair or build tissues. The important place of oxygen in the industrial world is discussed later in this chapter.

#### Abundance:

bined state?

We live in a vast ocean of sir, of which about one-fifth consists of free molecular oxygen. In the combined state, oxygen is even more widely distributed. It makes up eight-minths, by weight, of all the waters of the earth, almost one-half of the earth's crust, two-thirds of our bodies, and a large part of all vesetable matter.

#### COMPOSITION OF THE ATMOSPHERE (DRY)

Component	Percent by Volume	Formula	
Nitrogen	78 04	N <sub>2</sub>	
Oxygen	20 98	02	
Argon	0 94	Ar	
Other gases	0.04		

Because of its great importance and abundance oxygen is the natural element with which to begin the systematic study of typical chemical changes of the elements and their more important compounds.

#### SELF-TESTING QUESTIONS

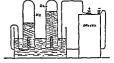
- Why is oxygen considered the most important element in our lives?
   Where is oxygen the most abundant in the free state? In the com-
- 3 Which element is the most abundant component of the atmosphere?

### II. PREPARATION AND PROPERTIES

## Preparation:

For commercial purposes a cheap and abundant supply of oxygen is usually obtained by evaporating the more volatile nitrogen from liquefied air. Oxygen may also be obtained, along with hydrogen, by decomposing water with electricity. This latter process is called electrolysis (Fig. 2). It is rather difficult to separate absolutely pure oxygen from the other gases in the atmosphere; therefore in the laboratory it is usually prepared by liberating it from some of its compounds. A convenient and common laboratory method of

Fig. 2—Decomposing Water. Electrolysis of water (H<sub>2</sub>O) forming two volumes of hydrogen and one volume of oxygen. How can you prove that the collected gases are hydrogen and oxygen?



obtaining oxygen is to heat potassium chlorate, a compound of potassium, chlorine, and oxygen. The chemical change in this case is represented as follows:

The ending "ate," as used in the compound "potassium chlorate," signifies a compound composed of three elements, of which oxygen is one. The ending, "ide," as in potassium chloride, is used for all compounds composed of two elements.

In the laboratory method of preparation it is customary to mix with the potassium chlorate some manganese dioxide. This causes the reaction to take place readily at a lower temperature than is otherwise possible.

A material like manganese dioxide, the influence of which either hastens or retards the speed of a chemical reaction, without being altered itself, is called a catalytic agent or simply a catalyst. In our study of many chemical reactions catalyzers will demand frequent attention. The action of a catalytic agent is comparable to a fore-

man of a group of men whose mere presence greatly improves the performance of the workers.

# Properties

Pure oxygen is a colorless, odorless, tasteless gas, slightly soluble in water. The most noticeable and important chemical property of oxygen is ability to combine directly with many other elements, especially at high temperatures.

#### Oxides

Almost all of the elements (metals and nonmetals) combine with oxygen to form a large class of compounds which are called exides Also many compounds already containing oxygen may unite with more oxygen, e.g., carbon monoxide (CO) to form carbon dioxide (CO<sub>2</sub>), and sulfur dioxide (SO<sub>2</sub>) to form sulfur throate (SO<sub>3</sub>) to form sulfur throate (SO<sub>3</sub>) to form sulfur throate (SO<sub>3</sub>) to form sulfur throate (SO<sub>3</sub>).

#### OXIDES

Metallic Oxides		Nonmetallic Oxides		
Sodium oxide	Na <sub>2</sub> O	Carbon dioxide Chlorine monoxide Nitrogen trioxide Phosphorus pentoxide Sulfur dioxide	CO <sub>2</sub>	
Calcium oxide	CaO		Cl <sub>2</sub> O	
Magnesium oxide	MgO		N <sub>2</sub> O <sub>2</sub>	
Bismuth oxide	B <sub>12</sub> O <sub>3</sub>		P <sub>2</sub> O <sub>5</sub>	
Cupric oxide	CuO		SO <sub>2</sub>	

Some naturally occurring oxides are water ( $H_2O$ ), carbon dioxide ( $CO_2$ ), sand ( $SiO_2$ ), and hematite ( $Fe\cdot O_2$ ). Notice that an oxide is a compound of oxygen with but one other element, and hence it is a binary compound. The oxides form a highly important group of compounds, one of the four large classes in morganic compounds—oxides acides, bases, and sails

## Oxygenation

The actual process of a substance uniting with oxygen is called oxygenation. The union may be rapid or slow, and is so slow in some instances that it is hardly perceptible that any change is taking place. Common examples of this slow oxygenation are the rusting of iron in the presence of moisture (Fig. 3), the decay of plant and animal matter, or the oxygenation of food materials in the body during respiration (breathing). It is by means of this slow

oxygenation of foods that the body temperature is kept constant and slightly higher than that of the surroundings. The body tissues are oxygenated only when worn out and dead, and even then the heat produced is negligible. Certain catalytic agents called enzymes (en'zims), in both animal and vegetable tissues, permit oxygenation at comparatively low temperatures of foods, tissues, and many substances found in the cells. In fact, it is oxygenation that produces the energy for maintaining body temperature, muscular contraction, glandular secretion, and nerve impulses. Another example of oxygenation which is of special interest and importance to the nurse is the destruction of certain disease-producing bacteria by free oxygen or by compounds which contain oxygen.



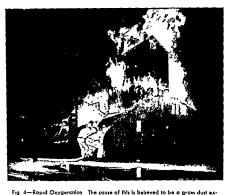
Fig. 3.—Slow Oxygenation. An Iron pipe destroyed by rusting or slow oxygenation. How can Iron be protected from oxygenation? Courtesy, New Jersey Zinc Co.

# Oxygenating Agents (Oxidants):

Three medicinal compounds parting with their oxygen readily and therefore used as oxygenating agents (oxidizing agents, oxidants) are the germicides hydrogen peroxide, potassium permanganate, and sodium hypochlorite. Anaerobic bacteria, as tetanus bacilli, cannot live in the presence of free oxygen, and consequently wounds infected with this kind of bacteria are kept open so that these organisms may be oxygenated and killed.

#### Combustion:

When oxygenation takes place rapidly enough to produce light as well as heat, the process is called burning or combustion. In a



rig 4—kepia Oxygentalion ine cause or inis is deleved to be a grain dust explosion. Which of the factors determining the rate of oxygenation is responsible for this fire? Courtesy, National Board of Fire Underwriters

broad sense, any energetic chemical combination accompanied by light is also known as burning or combustion whether oxygen is involved or not. Whether oxygenation is rapid or slow, provided that the same products are formed, the amount of energy produced is the same. The rate at which oxygenation takes place is governed by four conditions: (1) the nature of the materials undergoing oxygenation, e.g., wood as compared to coal; (2) the temperature of the materials being expressively respiration, for instance, is more rapid in warm blooded animals; (3) the concentration of the oxygen which surrounds the materials undergoing oxygenation; and (4) the extent of exposed surface, i.e., the greater the surface exposed the more rapid is the oxygenation.

Not only the rate of an oxygenation process, but the rates of all chemical reactions in general, are determined by the above four factors

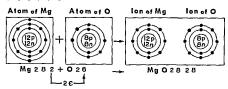
#### Oxidation and Combustion:

The combination of oxygen with an element produces a rise in the valence of the element. Thus, when metallic magnesium combines with oxygen, its valence is raised from zero to two  $(2Mg + O_2 \rightarrow 2MgO)$ . Similarly, the oxygenation of a compound always implies a rise in the valence of one or more of the elements in the compound (2 CO + O2 → 2 CO2). Now, other elements besides oxygen can raise the valence of another element either in the free state or in combination. Thus, when sulfur combines with magnesium to form magnesium sulfide (Mg  $+ S \rightarrow MgS$ ) the valence of the magnesium is raised from zero to positive two. This process in which the positive valence of an element which is either in the elementary state or in a compound is raised, whether through the action of oxygen or of some other substance, is known as oxidation. The element or compound on which this change is wrought is then said to be oxidized, and the agent which brought about the oxidation is known as the oxidizing agent (oxidant). Oxygenation reactions are. therefore, oxidation reactions at the same time, but in addition there are many oxidation reactions which do not involve oxygen and are therefore not oxygenation reactions.

The reverse process to oxidation is reduction. Reduction is the process in which the positive valence of an element is lowered, the agent producing the lowering being known as a reducing agent (reductant). In the case above of the combination of sulfur and magnesium, the valence of the sulfur is lowered from zero to negative two. hence in this case the sulfur is reduced.

# Oxidation and Reduction from the Electronic View:

It will be remembered from the discussion of the electron theory that, in some reactions, when combination of substances takes place, electrons are transferred from the atoms of some elements to the atoms of others. The valence of an element is considered to be zero in its free state; if the valence of an element is increased, its atoms give up some electrons, while if the valence of an element is lowered, its atoms receive some electrons. For example, when magnesium combines with oxygen to form magnesium oxide, each magnesium atom transfers two of its electrons to the oxygen atom with which it combines. Similarly, when magnesium and sulfur combine, each magnesium atom transfers two of its electrons to the sulfur atom with which it combines. The following diagram illustrates the valence changes (transfer of electrons).



F.g. 5.—Chemical change in terms of planetary elections showing the formation of ions through the oxidation of Mg (loss of electrons) and the reduction of oxygen (gain of electrons).

Oxidation has been defined above as an increase in positive valence. Now, in view of the electron theory, oxidation of an element can be defined as the loss of electrons by the atoms of that element. Similarly, reduction of an element may now be defined as the gaining of electrons by the atoms of that element. Since the electrons given up by the atoms of one element during a chemical reaction are taken up by the atoms of another element, it can be understood that oxidation and reduction always occur together. Thus there is no case of oxidation in which reduction is not also present or vice versa. Oxidation and reduction always take place to an equal degree. To summarize

# OKIDATION

Electrons are lost by substance oxidized Valence becomes more positive

or less negative

REDUCTION

Electrons are gained by sub stance reduced Valence becomes less positive

or more negative

Whenever oxidation reactions occur, heat energy is released. On the other hand reduction usually requires the addition of outside energy. For example it is the oxidation of foods in the body that releases energy and maintains the body temperature. Likewise it is the reduction of carbon dioxide and water by plants to form sugar and other carbohydrates that absorbs energy of the sun during the manufacture of plant foods. From this it is evident that with oxidation as our chief source of power and energy, and reduction as our chief method of power storage, oxidation and reduction reactions become one of the most important types of chemical changes.

# Spontaneous Combustion:

Frequently the heat produced by oxidation cannot escape, particularly when the material undergoing oxygenation is a poor con ductor of heat. At such times the temperature of the substance will gradually rise as oxidation progresses. This rise in temperature further increases the rate of oxidation and soon a temperature is called the thindhing temperature and the materials are said to have caught fire by spontaneous combustion. Only rags left by painters, slack coal in the closed hold of a ship, sawdust heaps, and damp fermenting hay in stacks are materials which often take fire because of spontaneous combustion. Nondrying oils such as mineral oils do not undergo spontaneous combustion, but they are combustible

# Another Form of Oxygen-

Frequently during lightning discharges, or during the operation of x ray machines, or other electrical apparatus, which produce an electrical discharge through air, the oxygen absorbs electrical energy and is converted into a form of oxygen called "ozone"  $(O_3)$ , which may be recognized by its peculiar pungent odor. In this change three volumes of oxygen are changed into two volumes of ozone

#### Uses of Ozone

Ozone is an active oxidizing agent and is very effective as a de odorizer and disinfectant, but even though it does remove odors and kill germs, it has not been of much practical use in purifying air or water Instead of using ozone for water purification chlorine usually is used, since chlorine is not only more effective but also cheaper In our own country ozone has been used to some extent in bleaching oils, waxes, flour, and starch Ozone is seldom in high enough concentration to kill the bacteria of the air, and along with its irritating effect on the lungs, is not to be considered as an ef fective disinfectant for air in hospitals or rooms. Although there are only traces of ozone in the air near the earth, because it reacts with the ever present water vapor to form hydrogen peroxide (H2O2), its presence in larger quantities at higher altitudes is im portant since ozone has the power to absorb some of the ultraviolet rays from the sun and thereby prevent these radiant rays from caus ing fatal sunburns and blindness. However, a small amount of these rays reach animal life and are instrumental in preventing the bone disease known as "rickets" Ozone is very similar to oxygen in its properties, but it is very much more active because of its greater energy content. Such different forms of the same element, as oxygen and ozone, which differ somewhat in their properties but chiefly in their energy content, are said to be allatropic forms. Phosphorus, sulfur, and carbon are other elements which have allatropic forms.

#### SELF-TESTING QUESTIONS

4 By what two commercial methods is oxygen obtained?

- 5 Define and give one example of electrolysis catalytic agent oxide, oxidation combustion enzyme, oxidizing agent spontaneous combustion kindling temperature
  - 6 Name three medicinal oxidizing agents
  - 7 What is ozone and what are its uses?

## III. FIRES

Since oxygen is associated with burning, which may be helpful or destructive, a brief discussion of fires and methods for extinguishing them is needed. In hospitals, rest homes, and similar institutions, where many of the patients are bedfast and practically helpless, fire prevention measures assume added importance. Personnel must be adequately trained in prevention of fire, and in procedures for combating fire quickly and effectively.

### Matches:

The "strike anywhere" or friction match tips are often composed of phosphorus suifide, potassium chlorate, and paraffin When the match is rubbed over a rough surface, the heat of firction raises the phosphorus sulfide to its kindling temperature. The potassium chlorate or some other conducting agent furnishes sufficient coygen to make the combustion more rapid. Enough heat is generated to cause first the paraffin and then the wood to burst into a flame and burn. Because of fire hazards the strike anywhere match, once known as the "parlor match," has been to some extent replaced by the sifety match. The head of this match contains antimony sulfide, a compound that is more difficult to ignite by firetion than phosphorus sulfide. The antimony sulfide is mixed with a suitable oxidizing agent, and the combination is held together with glue one side of the match box has been coated with a mixture of

powdered glass and red phosphorus, the red phosphorus being an aid in the ignition of the antimony sulfide Such a match is seldom ignited accidentally

## Fireproof Materials:

When a substance does not combine with oxygen it cannot burn, and it is then said to be "fireproof" Fireproof materials either do not combine with oxygen, except at high temperatures, or they already are completely oxidized. Asbestos and granite are well known examples of substances which cannot burn, they are the products of combustion formed by nature long ago. If clothing, wood, or any absorbent material is coated or saturated with certain oxides, or other incombustible compounds, the material then be comes fire resistant.

# Fire Extinguishers

Most chemical fire extinguishers contain some liquid which surrounds and often cools the burning fuel with a noncombustible gas. A common type of extinguisher uses water and carbon dioxide. In the soda and type, the carbon dioxide is generated as follows.

The water forced out by the carbon doxide cools and smothers the flame, much as would a wet blanket. In the clear water type, carbon doxide in liquid form is contained in a sealed carridge suspended in water. Both types, upon inversion of the extinguisher, pressurize the container and expel the water. A more recent type of fire extinguisher is essentially a portable steel tank which is charged with liquid carbon dioxide under pressure. Upon opening the valve the liquid carbon dioxide quickly evaporates and escapes as a cloud through a funnel shaped nozzle which can be directed on the fire (see Fig. 6, page 208).

Liquid fuels, like burning oil or gasoline which are lighter than water, do not mix with it and therefore float on top, and are best smothered without the use of water. It is for this reason that, in addition to the usual types of extinguishers, sand or a blanket is often kept in chemical laboratories to smother a fire.

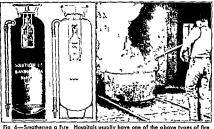


Fig 6—Smothering a Fire Hospitals usually have one of the above types of fire extinguishers available in the corridors for an emergency fire What is the position of the extinguisher when in use? Courtesy, Walter Kidde & Company, Inc

Foamite, a highly effective commercial fire extinguisher for use on burning oil or gasoline, contains alumnum sulfate in place of sulfuric acid, and in addation has a heorice extract which aids in forming a thick, tough foam filled with carbon dioxide bubbles. This foam acts as a blanket in excluding the oxygen. The light, insoluble solid, aluminum hydroxide, produced according to the following equation, makes the foam more durable:

$$AI_2(SO_4)_3 + 6 NaHCO_3 \rightarrow 3 Na_2SO_4 + 2 AI(OH)_3 \downarrow + 6 CO_2 \uparrow$$

It is interesting that this reaction is similar to that of an alum baking powder. A small portable fire extinguisher suitable for the home is the pyrene fire extinguisher (p 277), which contains liquid carbon tetrachloride. This liquid, when sprayed on a fire, volatilizes and surrounds the flame with a noncombustible gas to the exclusion of oxygen.

#### SELF-TESTING QUESTIONS

- 8 What materials are used in making a "strike-anywhere" match?
- 9 How does a safety match differ in composition from a "atrike anywhere"?
  10. Why is a safety match considered to be safe?
- 11. When is a substance fireproof?
- 12. How is absorbent material made fireproof?
- 13 What is the principle of the carbon dioxide fire extinguisher? Of the Foamite fire extinguisher? Of the pyrene fire extinguisher?



Fig. 7—Extinguishing Fire with Dry Chemical. This new type of extinguisher expels dry powder to coat over burning material. Why would this be effective? Courtesy of Fyr-Fyter Company

### IV. USES OF OXYGEN

# Oxygen in Nature:

Oxygen is an important constituent of the majority of the compounds in the earth and of the creatures on it. Most forms of animal life need oxygen to live. Land animals receive their oxygen from the air, while many aquatic animals obtain their oxygen from the air dissolved in the water. The oxygen in the air aids in reducing the refuse organic matter by a process called decay, which is further hastened by bacteria. In this way the earth is freed from a surface accumulation of dead plant and animal products, and in a similar way natural water is freed from pollution. It is the oxygen dissolved in water that is so important in the disposal of swage. For this reason the sewage is mixed with a large volume of water so that large quantities of dissolved oxygen will be available for oxidation purposes. Although oxygen serves a very useful purpose in producing decay, as in the case of dead plants and animals, still it is detrimental to the keeping of foods. As a consequence various ways are used to prevent this action such as refrigeration, cooking, canning, salting, drying, freezing, and smoking. Oxygen, too constantly eats away metal surfaces and the rust and corrosion that result percessent millions of dollars in waste annually.

## Oxygen in Industry

An important industrial use of oxygen is to produce high temperatures, as in the oxyhydrogen and oxyacetylene flames for welding metals, making repairs on machinery and cutting iron. The oxyacetylene flame gives a temperature as high as 3500° C. In cutting iron the oxyacetylene flame heats the iron and then with most of the acetylene cut off, the compressed oxygen rapidly burns away the iron. Cylinders of commercial oxygen for the above purposes are familiar objects in automobile service stations. In recent years the steel industry has been using increasing quantities of oxygen to operate furnaces.

# Oxygen in Medical Practice

The therapeutic uses of oxygen in impeded respiration (pineu monia), in treatment of poisonous vapors as nitric acid fumes and in conjunction with anesthesia are discussed under Physiological Correlations (p. 55)

#### Air Conditioning

For years ventilation has been the only means of supplying us with healthful ar: Investigation has shown that the injurious effects of ad ventilation are not so much due to a low percentage of oxygen or an excess of carbon dioxide in the air but rather to high temperature, an abnormal amount of uater vapor (humdity), and poor circulation of air

A closed area containing many people does not provide adequate ventilation There is nothing quite so uncomfortable as the lack of ventilation, and for that reason many hospitals dwellings public buildings, and transportation devices such as trains, airplanes, and automobiles have established intricate systems to provide proper air conditions Air conditioning is the simultaneous control of (a) temperature, (b) humidity, and (c) air movement. These three factors must maintain a definite relationship to each other in order to unsure bodily comfort We warm or cool our rooms just enough so that the body loses heat at a comfortable rate The body gets rid of its surplus heat by radiation and conduction to the surrounding air, and by evaporating moisture at the surface of the body A high temperature decreases the rate at which the body can lose its heat by direct conduction, while a high humidity decreases the rate at which moisture can evaporate Low temperature produces opposite effects Evidently then the ill effects of bad ventilation are the result of interference with heat regulation of the body The air move ment is necessary to maintain an adequate supply of fresh air, otherwise the body breathes expired air, saturated with moisture at body temperature, and consequently very little heat can be eliminated by radiation, conduction, and evaporation When any one of these three factors is out of proportion the body becomes uncomfortable It is air conditioning which regulates and maintains these proper conditions

#### SELF-TESTING QUESTIONS

- 14 How does oxygen purify the land?
- 15 What are the chief industrial uses of oxygen?
- 16 What is air conditioning?
- 17 What factors are considered in air conditioning?

# V. PHYSIOLOGICAL CORRELATIONS

### Respiration:

Oxygen in Breathing Oxygen combines loosely with the hemoglobin, the respiratory pigment in the red corpuscles of the blood. There is also a little oxygen dissolved in the blood. Taken together the combined oxygen and the dissolved oxygen make nearly as high a percentage of oxygen in the blood as in the air Hemoglobin, combined with oxygen, is bright red (arterial blood flowing from the lungs), but after giving up its oxygen to the blood capillaries it is a deep bluish purple (venous blood). This is the reason for the different color of blood flowing from arteries and from the vens

The oxygen circulates through the tissues in all parts of the body,

oxidizing the sugars, fats, all broken down material, and certain poisonous substances, with the formation of heat, lactic acid, carbon dioxide, and water. The speed of the oxidation is influenced by enzymes called oxidases, which act as catalyzers. The water is eliminated by the kidneys, sweat glands, and lungs. The carbon dioxide is carried by the blood to the lungs and then exhaled. A



Fig. 8—The Breath of Ufe. Oxygen mixed with a small amount of carbon dioxide as a respiratory stimulant is being used in reviving a newborn baby. Courtesy, Ohio Chemical and Mfg Co.

considerable amount of the lactic acid is converted into a carbohydrate called glycogen which is then deposited in muscle tissue and in the liver. Glycogen, which is also derived from sugar, is a highly important source of energy for the body.

Exercise, of course, brings on a more rapid oxidation, which is always followed by hunger. Especially is this noticeable in children. The normal temperature of the body is 37° C. (38.0° F.), and the automatic control of the oxidation which keeps this temperature constant is one of the most marvelous functions of the body. If the waste products, i.e., the products of oxidation, are not carried away by the blood, fatigue results, as indicated in Chapter I.

The gas, carbon dioxide, exhaled by the lungs, is a food for plants. The carbon is retained in the tissues of the plant, while the oxygen is returned to the air. Thus animals and plants work together in keeping the amount of oxygen in the air constant

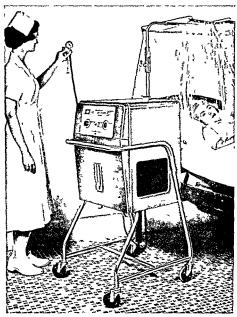


Fig. 9.—Oxygen Tent. This clear view oxygen tent is used with the hosp fall central pipeline oxygen system. Note the control at the wall outlet. What are advantages of a central supply system? Courtesy, Ohio Chemical and Surgical Equipment Company.

OXYGEN IN MEDICINE Pure oxygen finds an important use in the hospital, especially in the operating room (Fig. 8)

There are pathological conditions in which the cells of the body do not receive a normal supply of oxygen from the blood. Such a condition is known as hypoxia (oxygen shortage) and usually may be controlled with an atmosphere of about 50 per cent oxygen. The oxygen for this purpose is stored in steel cylinders and its administration is regulated by observing the rate of flow through a bottle containing water or by a pressure gauge.

A modern method of administering oxygen consists of an oxygen chamber in which the patient is placed in bed although the oxygen tent is more commonly used in most hospitals. The amount of oxygen to be given is regulated by a motor. In some of our newer hospitals oxygen is piped to beds from a central supply (Fig. 9)

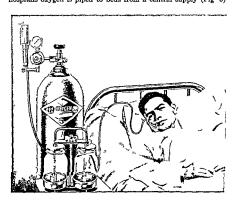


Fig. 10—Oxygen Inhalator. The oropharyngeal cathete, out it is of special value for high concentrations of oxygen and as a substitute for an oxygen tent when tent is not over able. What is the advantage of the humidity ng and dr. p lar assembly as shown to the patients of the gold Courtery. The Ohio Chemical & Mifg. Co.

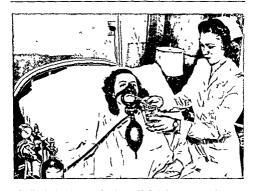


Fig 11—Nasal Mask. The nasal mask is switable for high concentrations of oxygen or oxygen helium therapy. Why is this type of mask convenient in the hospital, and much preferred on commercial air lines? Courtesy, The Ohio Chemical & Mfg. Co.

A much more economical method of producing a high concentration of oxygen in the blood is by means of the nasal catheter (tube), the insertion of which in one nostril with oxygen flowing briskly (two liters per minute) will supply an inspired air containing 30 to 35 per cent of oxygen, while the use of two catheters furnishes about 40 per cent oxygen (Fig. 10). A convenient type of nasal mask is shown in Fig. 11.

The objections to the uncomfortable use of a nasal catheter, and the initial expense of the other methods mentioned, have resulted in still another method of administering oxygen (Fig. 12).

In cases of accidental interference with respiration, such as occurs in asphyxia (condition of lifelessness) and drowning, where normal respiration is either interfered with or cut off for short periods, oxygen is administered in a concentrated form by means of an inhalator. With this apparatus (Fig. 13) regulated amounts of oxygen are released through a rubber mouthpiece into the



Fig. 12—An Open Top Oxygen Tent. The air is kept cool by a small ice container back of the patient's head. An oxygen flow of four liters per minute maintains a concentration of about 50 per cent around the patient's face. What are the advantages that can be claimed for its type of tent? Courley, Warran E. Coll in. Inc.

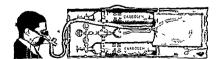


Fig. 13—Oxygen Inhalator. The oxygen inhalator is used in cases of asphyxia as in drowning and exposure to possonous gases. Artificial respiration is applied with the administration of oxygen. What municipal department should be equipped with inhalators?

patient's mouth, thus bringing the oxygen content of the blood up to normal.

In certain types of surgery, such as dentistry, nitrous oxide (laughing gas) is used as an anesthetic. Oxygen is mixed with the nitrous oxide to avoid asphyxiation. Any inflammation in the lungs caused by an abnormal condition (reduced pressure) of the air will interfere with the normal supply of oxygen to the blood, and healthy



Fig 14—A Face Tent This newer device is designed for maximum patient comfort. What are some of its advantages compared to the conventional oxygen tent? Courtesy, Ohio Chemical and Surgical Equipment Company.

persons will begin to show symptoms of oxygen hunger. This is especially true with aviators, miners, and deep-sea divers Such persons must frequently resort to the use of pure oxygen. This is supplied from cylinders in carefully regulated amounts, through the breathing helmets. The lightness (92 per cent of the lifting power of hydrogen) and rapid diffusibility of helium gas has made possible an oxygen-helium agent for use with anesthetics in the treatment of asthma, pneumonia, and other respiratory diseases. The helium eases the burden on weakened lungs. It is used as a synthetic air (80 per cent He, 20 per cent O<sub>2</sub>) for deep-sea divers and under-



Fg 15—Helium Oxygen Therapy. Hel um because of its low specific grav ty os compared to air [0 138 to 1] and its consequently high of flus hilty recently has found a use for the rel ef of var ous types of respiratory obstruct on. How will the add to not hel um to goseous anesthet as affect the muscular effort of breath ina? Courteer 10b of home aid and Mia Co.

water tunnel workers to decrease the danger from causson disease or the 'benda," a painful condition caused by sudden expansion of nitrogen from the air dissolved in the blood. This use of helium to replace nitrogen depends upon the fact that helium is about 40 per cent less soluble in the blood than is introgen (Fig. 15).

Oxygen finds another important use in the hospital in ascertain ing a patient's basal metabolic rate. The basal metabolism is the smallest amount of energy required to maintain life when all activity is reduced to a minimum. In practice this is measured by determining the amount of oxygen consumed in a given period by the patient when at rest. The basal metabolic rate, then, indi-

cates the lowest amount of energy required for the body to maintain normal metabolism. Any metabolic rate above normal is indicated by + and below by -. Since there is a normal rate of metabolism in good health, any deviation one way or the other, if excessive, may be an indication of either a present or a future trouble.

# Oxygen Requirement:

The place and value of oxygen with respect to maintaining life deserve some discussion. Even when the body is perfectly quiet and there is no food to be oxidized, the average person requires some 15 to 18 ml. of oxygen per inspiration. If we consider that approximately one-fifth of the air is oxygen, and that one-fifth of the oxygen in the lungs is absorbed by the blood from the lungs, the amount of air inhaled at every inspiration must be about 25 times 15 or 18 ml., or about 400 ml. per inspiration. The amount of the air intake of course will be greatly increased when food is ingested and the person is actively engaged in some form of exercise. To meet any sudden demand of the tissues for oxygen, alteration in lung ventilation must take place, since the body is not capable



Fig 16—A Resultatator This instrument provides gentle positive and negative pressures to restore natural breathing. Why is the position of the head of the patient of importance? Courtesy, Ohio Chemical and Surgical Equipment Company.

of storing a reserve supply of oxygen as it ordinarily may do in the case of foods.

If for some reason as in drowning, gas poisoning, and other forms of suffocation, the respiratory mechanism of the body becomes in capable of supplying the tissues with the necessary amount of oxygen, destructive action begins in the cells, and prompt measures of resuscitation must be used. This lack of oxygen in the body. hypoxia, is generally relieved by prompt oxygen therapy (Fig. 13) However if the condition has been gradual and over an extended period, as in circulatory disturbances of cardiac origin in anemic conditions or in inflaminatory conditions of the lungs where there has been fever associated with disease, and also where the demand for oxygen in the tissues has been greatly increased—then the cells of the nervous system in particular, the heart and other organs of the body will have been damaged to such an extent that even oxygen therapy may be ineffective. In such cases, oxygen therapy may not be considered a specific any more than would be food to one who through starvation has passed beyond the point of assimilation

It is interesting to know that a candle goes out in air which con tains less than 17 per cent of oxygen, but human life will continue, provided other conditions are normal

From these brief statements it is evident that there are various types of hypoxia, produced by inadequate oxygenation, such as those encountered in pulmonary involvements, circulatory dis turbances and in lessened enperity of the blood to carry oxygen



F a 17—Effect of Decreasing Pressive of Oxygen. At all all tudes the ar con tons approximately 21 per cent oxygen. The effect of a decreasing pressive of oxygen on the human body is illustrated in the photographs of a burning candle of baromethic pressives corresponding to elevations of 1000 5000 to 000 and 25 000 test. Does this correspond to the weakness of the human body and denger of tudden collapse when there is not a normal supply or part of pressive of oxygen in the lungs.

## Symptoms of Hypoxia:

In asphyxia, oxygen deprivation is very rapid, loss of consciousness ensuing with possible convulsions before death. At such times, the most effective treatment is artificial respiration, or the inhalation of oxygen mixed with carbon dioxide, the carbon dioxide being used to stimulate deeper breathing.

On the other hand, slowly developing hypoxia impairs the mind and senses to such an extent that the patient is almost unaware of his condition. The pulse is rapid and feeble, the symptoms being somewhat like the effect of an overdose of alcohol. Headache, excitement, and loss of self-control may follow. The unrecognized failure of judgment on the part of one suffering from slowly developing oxygen shortage is a serious danger because the victim persists in continuing his activities at a time when his condition calls for rest and more oxygen He does not recognize these delayed symptoms until too late for remedy.

As already mentioned, at sea level approximately one-fifth of the air is oxygen. However, at higher levels, as on mountain tops, the lowered atmospheric pressure diminishes the oxygen per unit volume of air (Fig. 17) to the point where all body functions are

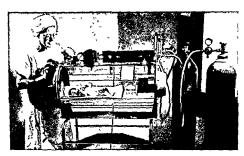


Fig 18—"Air Lock" Helps Bables Breathe. The oxygen-air pressure lock approximates the air pressure, oxygen supply, temperature, and humidity prevailing in the womb just before birth. Air pressure fluctuates automatically, serving to draw out mucus which might choke the infant. Courtesy, Lovenstein Corp.



Fig. 19—Portable Oxygen Cylinder. This makes possible oxygen therapy on a first a dibass. The equipment is relatively inexpensive. Where might equipment of this type be made available for emergency use? Courtesy Linde Division. Unlike the Caracteristics.

more or less inhibited Respiration may even fail temporarily, re sulting in fainting or syncope or the heart itself may fail to function

## Guide for Oxygen Therapy

There are many symptoms of oxygen starvation The nurse, and the anesthetist in particular, must be on the outlook for indications of a lack of oxygen in the patient A blue colored skin called cyanosis (is an-osis), is a typical symptom of asphyxia Blue finger tips and cyanosis of the face constitute the most reliable index of hypoxia and the need for immediate oxygen therapy When cyanosis is evident, the pulse is rapid and the respirations are quick

ened, but they are more shallow than normal In combating this condition by increasing the oxygen concentration of the inspired air, it has been observed by different investigators that the higher the concentration of the oxygen the slower will be the pulse A slow pulse then will indicate that the patient is breathing more deeply and that hypoxia is being relieved. From this it is evident that the pulse can act as one of the best guides in determining the need for oxygen, even before cyanosis is evident.

Within recent years, experiments have shown that the optimum concentration of oxygen for therapy is somewhere between 40 and 60 per cent, and that any concentration below 30 per cent is of scarcely any value Higher concentrations of oxygen, with the likelihood of not getting enough CO<sub>2</sub> in the inspired air to stimulate the respiratory centers in the brain, tend to suspend breathing. The nasal catheter method that is commonly used in hospitals supplies up to 35 per cent of oxygen, an amount which, if continued, will provide for the patient's comfort

A new development in the medical use of oxygen is termed hyperbaric (high pressure) oxygen therapy. Here the patient, and those immediately attending him, are subjected to elevated oxygen pressures with the result that more than the normal amount of oxygen is carried in the blood stream. Huge pressure chambers are constructed to utilize oxygen in this fashion. At the present time this type of oxygen therapy appears promising, but it is still largely in the experimental stages.

### SELF-TESTING QUESTIONS

- 18 What is the relation between oxygen and hemoglobin?
  19 In what ways is oxygen used in hospital practice?
- 20 What is the difference between hypoxia and cyanosis?
- 21 Can hypoxia exist without cyanosis?
- 22 What has the basal metabolic rate to do with oxygenation in the body?
- 23 What is oxygen therapy? What is the requirement of oxygen by the body?

## SUGGESTED ACTIVITIES

- I THOUGHT PROVOKING QUESTIONS
  - 1 Why is so much of the earth's oxygen found in combination?
  - 2 Why do not only rags used by mechanics undergo spontaneous combustion?
  - 3 Name three fireproof substances and explain why they are fireproof
  - 4 Explain the successive use of paper wood and coal in producing a coal fire

- 5 What precautions must be observed to prevent surgical instruments from rusting? To prevent plant and animal food from decaying?
- 6 In extinguishing a fire what principles must be kept in mind? 7 What precautions should be observed to prevent spontaneous
- combustion? 8 Does the term "combustion" always involve oxygen? Explain
- 9 Why is oxygen considered the most important element?
- 10 Why is oxygen essential to life?
- 11 Vegetable or drying oils on cloth may undergo self ignition. Why do not oils used on dusting cloths and more start fires? 12 In a mine where a candle will burn, a man may get enough oxygen
- to live How do you account for the fact that a candle will burn on top of Mount Everest, but man cannot live there?
- 13 How do you explain that fanning a fire may in some instances put it out and in other cases makes it burn better?
- 14 What factors determine the rate of oxygenation of the aluminum in a photofiash bulb?
- 15 How do you account for the fact that housewives have been killed by throwing dust collected from floors into an incinerator or furnace?
- 16 In what common disease is there insufficient lung tissue to absorb adequate oxygen from the air?
- 17 How can you identify a gas having no color, odor, or taste?
- 18 How does hypoxia differ from anoxia?

II VOCABULARY TESTING OF NEW TERMS electrolysis hemoglobin

combustion enzyme

oxygenation spontaneous combustion ordation kindling temperature reduction hурохи

inhalator oxidase cyanosis вупсоре

asphyxia

basal metabolism

III TOPICS FOR ORAL OR WRITTEN REPORTS

1 Fireproof Textiles

catalytic agent

orde

- 2 Chemical Fire Extinguishers
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#### LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on page 650

# WATER-THE MOST IMPORTANT LIQUID

#### CHAPTER OUTLINE

I	OCCURRENCE AND PROPERTIES	IV	HARD WATER					
	(a) Occurrence		(a) Objections to use of har					

(b) Physical properties water (c) Chemical properties (b) Water softening

(c) Permutit process of water II IMPURITIES IN NATURAL WATER

softening (a) Mineral water (d) Exchange resins

(b) Organic matter V PHYSIOLOGICAL IMPORTANCE OF WATER (c) Analysis of water

(a) A component of protoplasm III PURIFICATION OF WATER and tissues

(a) Distillation (b) A component of all body

(b) Boiling fluids (c) Filtration (c) A tissue lubricant

(d) Agration (d) A temperature regulator (e) Sewage disposal (e) An aid in digestion

### 1 OCCURRENCE AND PROPERTIES

Just as we are said to be living in an industrial age of metals, so can it be said that we are living in an age of water chemistry, if we think of water in relation to our daily life In fact, the history of the rise and fall of civilizations and of mankind's economic progress could be written in terms of water-water for navigation, water for irrigation, water for power, and water for drinking and sanitation.

## Occurrence:

Water is the most familiar and abundant of all chemical compounds Large sections of the colder regions of the earth are covered with it in the form of ice; in the liquid state, it covers about five-sevenths of the earth's surface. The soil contains water which is necessary for the growth of plants, and water vapor is an essential constituent of the atmosphere Water constitutes more than half the weight of all living organisms and about two-thirds the weight of the human body Of the amount of water in the human body one-half is in the muscles, one-fifth in the skin, and one-fourteenth in the blood Practically all foods contain high percentages of water as shown in the following table

Tomatoes	94 3 per cent	Bread	35 3 per cent		
Milk	870 " "	Beans, dried	126 " "		
Apples	846 " "	Rice	123 " "		
Potatoes	783 " "	Flour	119 " "		
Beef	738 " "	Butter	110 " "		
Eggs	73 7 " "	Oatmeal	73 " "		

# Physical Properties:

Pure water is a colorless, dorless, tasteless liquid. In large quantities it may show a bluish or greemish tinge, caused by the reflection and refraction of the light rays and the organic matter suspended in it. It freezes at 0° C \* and boils at 100° C. When water is cooled it contracts until it reaches a temperature of 4° C. where it has its greatest density. At this temperature one milliliter (ml.) of water weighs one gram. The density of water at 4° C is used as the basis for computing the specific gravities (sp. gr.) of liquids and solids Specific gravity is the ratio of the weight of one milliliter of the sustance to the weight of one milliliter of the sustance to the weight of one milliliter of the sustance to the weight of one milliliter of mater. The specific gravity of mercury is 13 6, which means that one milliliter of mercury is 13 6 times as heavy as one milliliter of water. For expressing the specific gravity of agas, either hydrogen or air is used as a standard

When water is cooled from 4° C to 0° C, its freezing point, a slight expansion occurs In freezing, water expands by about one tenth of its volume This explains why water, in freezing, bursts water mines and why ice floats on water

Water requires more heat than any other liquid or solid to raise a unit mass of it (one gram) through a unit change in temperature (1° C) This heat is called specific heat and means that water has a specific heat of one calorie per gram per degree C. It has a great heat capacity, and undergoes temperature change more slowly than any other substance. This explains its use in the hot water bottle.

Water also has a high heat of vaporization, it requires 539 calories of heat to change a gram of water at 100° C to vapor These two factors, specific heat and heat of vaporization, explain how the human body maintains its constant temperature. In the change of the vapor back to liquid water, 539 calories of heat will be given off. This is called the heat of condensation. It is the high value of heat of condensation that makes steam useful for heating buildings, and it further explains why live steam causes more serious burns than hot water.

When one gram of see at 0°C changes to water at the same temperature, about 80 calones of heat are absorbed this heat is known as the heat of fusion. This is why see packs are used to lower body temperature. Each gram of see in such a pack absorbs 80 calones of heat from the body in melting. In order to change a

<sup>\*</sup>A comparison of the Cent grade (C) and the Fahrenheit (F) scales occurs on page 626

gram of water at 0° C. to ice at that temperature, 80 calories of heat must be extracted from the water. this heat is known as the heat of solutification of water. It is this operation which is carried on in ice-making plants.

Following are some important physical constants for water:

Freezing point	0° C.
Boiling point	100° C.
Specific gravity	1
Density .	1 Gm per ml
Specific heat	1 cal per Gm per degree C
Heat of fusion	80 cal per Gm
Heat of vaporization	539 cal per Gm
Heat of condensation	539 cal per Gm
Heat of solidification	80 cal per Gm

Water is remarkable for its ability to dissolve other substances, and it is the most universal solvent known. In fact, even substances like rocks are soluble to a slight extent. Pure water is used in laboratories in making up solutions because most substances dissolve readily in water and chemical action takes place more rapidly in solution. For example, the ingredients in baking powder begin to react as soon as the powder is dissolved. From a biological standpoint the solvent properties of water are of great importance to living organisms as through this medium nutrients are carried to the cells, and waste products away from them

Fig 1—Water, the Universal Solvent In the dry regions water is conveyed by flumes to fields so that animal foods may be made available to the plant. What classes of foods are made available to the body by solutions? Courtery, Eastman Teaching Films, Inc.



## Chemical Properties:

Water enters into direct combination with a number of elements and many compounds to form crystalline substances called hydrates. A hydrate of special interest to nurses is calcium sulfate or gypsim, the partially dehydrated form being called "plaster of Paris". The latter hydrate when mixed with water "sets" into a hard mass, and finds extensive use in making surgical casts. At such times a coarse mesh bandage (crinoline) is covered with the plaster of Paris powder. The bandage is applied and is then moistened with water, or it is dipped in water, wrung out, and then quickly applied. Since the paste expands slightly upon setting it is necessary to watch the circulation of the part of the body enclosed. The reaction is shown in the following equation.

(CaSO<sub>4</sub>)<sub>2</sub> H<sub>2</sub>O + 3 H<sub>2</sub>O → 2 CaSO<sub>4</sub> 2 H<sub>2</sub>O

Plaster of Pars
(soft powder)

Cypsum
(hard soft)

Notice that the setting of plaster of Paris is a chemical change wherein one hydrate is converted into another

When a hydrate like alum is heated in a test tube, drops of water condense in the cooler part of the tube, leaving a white powder called "burnt alum" " The water which assists in the formation of crystals, is called water of crystallization, or water of hydration (Fig 2). In this connection, it should be remembered that some crystalline substances like sugar and salt contain no water of hydration and are called anhydrous compounds. Sometimes the water of hydration is slowly given off when a crystalline hydrate is exposed to the surrounding dry air, and the crystal crumbles to a powder Crystallized washing soda is such a compound and it is said to be efflorescent. On the other hand, a compound such as anhydrous calcium chloride which takes up a troospheric water, is described



as hygroscopic Substances that are sufficiently hygroscopic to finally pass into solution are said to be deliquescent

Although water is a very stable compound that resists decomposition by heat, and is not a very effective oxidizing agent, it does react with many elements. Active metals like sodium and calcium displace hydrogen from cold water.

2 Na 
$$+$$
 2 HOH  $\rightarrow$  2 NaOH  $+$  H<sub>2</sub>

while others like magnesium and iron displace hydrogen only from steam

Certain nonmetals react with water It is the oxidizing action of steam upon glowing coke (carbon)

$$C + H_2O \rightarrow CO + H_2$$

that furnishes one of the cheapest sources of hydrogen, this mixture of gases, carbon monoxide and hydrogen, is an important fuel called water gas. A few active nonmetallic elements like chlorine, instead of liberating hydrogen as some metals do, react with the hydrogen in water to liberate oxygen.

$${
m H_2O} + {
m Cl_2} 
ightarrow {
m HCI} + {
m HCIO}$$
 (hypochlorous oc d)   
  $\downarrow$    
  ${
m HCI} + {
m O}$  (nascent oxygen)

Water unites with some oxides (called anhydrides) to form bases and with others to form acids. Thus with some oxides of metals it forms bases (lime changed to calcium hydroxide), while with some oxides of nonmetals it forms acids (carbon dioxide with water changed to carbonic acid, i.e., soda water). Reactions of water with many compounds, such as foods, to break them down into simpler substances, a process called hydrolysis, are discussed later in the book.

Under the discussion of analation you learned that iron rusts in presence of moisture. It has been found also that other chemical reactions will not take place unless a trace of moisture is present. For instance dry hydrogen gas, sulfur, phosphorus, and carbon will not burn in perfectly dry oxygen. This evidence proves that water is a very important catalyst probably the most important of all

#### SELE-TESTING OUTESTIONS

- Name four results of the absence of water in the human body
   State the occurrence of water
- 3 What are the chief physical properties of water?
- 4 What is specific gravity? Specific heat? Heat of vaporization?

- 5. Why is the temperature of the body constant?
- 6 What is a hydrate?
- 7. What is water of crystallization?
- 8. Why is plaster of Paris used in making surgical casts?
- What two large classes of compounds are formed when water unites with anhydrides?
- 10 How do some nonmetallic elements differ from active metals in the

#### II. IMPURITIES IN NATURAL WATER

Since water is an excellent solvent, naturally occurring water contains more or less matter derived from the soil with which it has come in contact and through which it has percolated. Sea water, for instance, contains about 3 per cent of ordinary salt. Even rain water contains dirt, and gases such as CO<sub>2</sub>, N<sub>2</sub>, and O<sub>2</sub>, dissolved from the air. This foreign matter in water is either mineral or organic matter, and may be either dissolved or suspended in the water.

#### Mineral Matter:

Common salt and various compounds of calcium, magnesium, and iron constitute the usual mineral content found in natural water. If the quantity is abundant the water is difficult to lather with soap and is called hard water, while water which contains little or no mineral matter lathers easily and is called soft water.

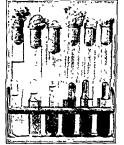


Fig 3—Testing Water for Sewage Contamination Bocillis call in water is an indication of sewage contamination, office of 6 no organism whose habitat is the colon of man. This regenism decomposes milk sugar with the formation of acid and gas. The three tubes on the left show this gas formation, the inverted inner tube acting as a gas trap. What common diseases are often traceable to water contamination! Courtery, E Buchanan, Chrestond, Division of Health.

## Organic Matter:

Products derived from the decomposition of plants and animals, and possibly from sewage, comprise the organic matter which is partially suspended and partially dissolved in the water. This organic matter serves as food for bacteria, many of which cause disease Water from shallow wells and rivers in thickly populated districts is quite apt to be highly contaminated with pathogenic germs Typhoid fever, dysentery, and cholera are often contracted by drinking water which has been polluted by bacteria carried by those afflicted with the disease. Sickness, directly traceable to water, frequently is due to these disease bearing organisms

# Analysis of Water:

By evaporating a definite amount of water to dryness and weighing the residue, the total amount of solid matter in the water can be determined. An examination of the composition of the residue is called mineral analysis.

ANALYSIS (PARTS PER MILLION) OF PUBLIC WATER SUPPLIES

		Metals				Radicals				
City	Solids	Calcum	Magnessum	Iron	Sodium	Bicarbonate	Sulfate	Chloride	Nitrate	Hardners (as CaCO <sub>3</sub> )
New York, N. Y	28	45	12	0 04	11	11	77	10	0 49	16
Philadelphia, Pa	70		33	0 07	54	46	120	29	1 10	44
Detroit, Mich	99	270	70	0 20	20	102	74	4.5	0 08	96
Cleveland, Ohio	159	35 0	84	0 07	5.6	13	25 D	110		122
Chicago, Ill	183	36 0	100	0 40	Na 4.6	144	100	60	1 80	131
St Louis, Mo	187	26 0	51	0 11	26 2	40	73 0	100	11 00	86
Los Angeles, Cal	279	39 0	160	0.0	34 0	165	59 0	28 0	Trace	163
San Francisco, Cal	369	38 0	18 0		70 0	276	36 0	76 0	1	166
Tampa, Fla	1273	1130	33 0	0 48	275 0	176	92 0	548 0	2 80	418
		'	1	1						

An analysis of this kind is of great importance in determining whether the water in question would be adaptable for manufacturing purposes, such as for use in steam boilers and in laundries. An examination to determine the amount of organic matter, the composition of the products (mostly ammonia, nitrites, and nitrates), and the number and kind of bacteria living upon the organic matter is called santary analysis. Making such an analysis is necessary for the health of any community. It is not sufficient merely to make a bacteriological analysis. In this connection, it is important to remember that the appearance of water is not a criterion of its purity, for clear, sparkling water is otten contaminated with dangerous germs. Only a trained chemist and bacteriologist should be employed to make a trustworthy analysis of water.

#### SELE-TESTING OUESTIONS

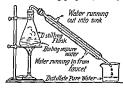
- 11 What constitutes mineral matter in water?
- 12 When is water soft?
- 13 What comprises the organic material in water?
- 14 What diseases may be caused by contaminated water?
- 15 What is a mineral analysis? A sanitary analysis?

## III. PURIFICATION OF WATER

Because all natural waters contain bacteria, some of which are disease causing (pathogenic bacteria), and because water contain nated with sewage is potentially very dangerous to health, different methods of purification have been worked out By some methods the harmful impurities, mostly pathogenic bacteria, are removed, while by others these harmful impurities are only partially removed and the remainder are destroyed

#### Distillation:

Boiling water and condensing the steam, called distillation, is the most effective but not the cheapest method of purifying water (Fig 4) The mineral matter and most of the organic matter are left in the vessel in which the water was boiled. The distilled water, as it is called, is used in the manufacture of ice, to some extent for drinking purposes, and by chemists in making solutions.



Fg 4—Purifying Water Distillation does not apply merely to water Why is distilled water used in the laboratory?

### Boiling:

Water may be made fit for drinking purposes by boiling, a process which does not remove any dissolved solid material, as the minerals, but does kill the microorganisms which cause disease. This is the simplest method of purifying water for hygienic purposes For the household supply the water should be boiled about fifteen minutes. During the boiling of the water the dissolved air is expelled. This causes the water to taste flat, but the flat taste may be overcome by aeration, as in the pouring of water from one vessel to another.

### Filtration:

The suspended matter in water, such as clay and undissolved organic matter, may be removed by filtration, a very economical method of purifying water. On a small scale this can be accomplished by passing the water through some porous clay, such as the Pasteur filter which consists of an unglazed porcelain cylinder



Fig. 5—A Slow Sand Filter. What Is an objection to this method of filtration?

surrounded by a metal case. In this way bacteria and suspended matter are filtered from the water as it passes through the porcelain to the inside of the cylinder. Substances in true solution, however, cannot be removed by filtration. Such filters are not very satisfactory, as they are not easily kent in working order.

On a large scale, in cities where the water supply comes from muddy rivers or a polluted lake, the water is allowed to pass skutly through beds of sand and gravel (Fig. 5), a purely mechanical process. The suspended matter is caught by the sand, but the dissolved impurities still remain in the water. Since not all of the bacteria are on the suspended organic matter, this water is not wholly suitable for household uses.

In the more rapid sand filtration plants, involving both a mechanical and a chemical process, the water before filtration is run into large tanks. Here it is made slightly alkaline, then thoroughly mixed with either aluminum sulfate, iron sulfate, or sodium aluminate to produce a flocculent solid in the water. This insoluble solid settles, carrying with it a part of the suspended particles (Fig. 6). The partially purified water is then run through the rapid sand filters, which remove most of the remaining organic matter (Fig. 7). As filtration does not always remove all the bacteria, it has become

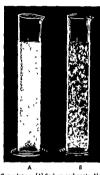
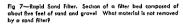


Fig 6—Coggilation IAI Sadium carbonate, Naj-CD<sub>2</sub>, percipates finely dwided particles of Colorum and magnesium with dan not readily settle and are difficult to filler. (BIA mare flacculent prespitation caused by such precipitants or coggilants as sodium cluminate, Na/O<sub>2</sub>, and adminimation of the compounds of the Colorum and Colorum precipitated compounds offect clarification? Courtery, Notional Aluminia (Colorum) and Colorum (Colorum).



the practice to treat the water with chlorine, a substance which kills the remaining micro-organisms. In some plants ammonia gas is fed into the water previous to the treatment with chlorine The ammonia gas unites with the chlorine to form chloramnes which



are in themselves strong bactericidal agents and have the advantage of prolonging the effect of the disinfection throughout the dis

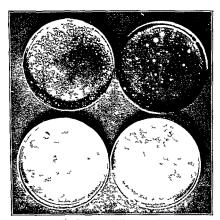


Fig 8—Before and After Treatment with Alum A vaual reproduct on of water purfact on The who the data in each plate are colonies of bacteria. The upper profit is from unheated raw water. The upper right is of this water after alum has been added. The lower left is the same water after (first on The lower right with the fewers that cat ons of bacteria colonies is again the same water after sed mentat on filtrat on and chlar nation. Does filtration remove all bacteria? Courtey F & Buchanon Cleveland D vs on of Health

tributional system In addition the chloramines dispel chlorinous tastes and disagreeable odors. In a few cities activated carbon a finely divided and specially treated carbon having the ability to condense and hold certain gases is also used to remove tastes and odors due to algae growths.

### Aeration:

When exposed to the air, water, in time, purifies itself. The oxygen of the air dissolves in the water, acts chemically on the bacteria, and destroys them. The oxygen also oxidizes the suspended organic matter into soluble products, thus depriving the bacteria of food. This process, however, should not be relied upon to render water fit for drinking purposes, because the contaminated water may not have had sufficient exposure to the oxygen of the air to kill all the bacteria. Some cities spray their drinking water into the air, others agitate it by bubbling air through the water or by allowing the water to flow over a series of tile cascades in order to cause a better oxidation of the organic matter and any other substances which ordinardy might impart an unpleasant taste and odor. This method of purification is called aeration (Fig. 9).

## Sewage Disposal:

Because of the importance of having water free from disease germs, the problem of supplying the community with safe water is closely related to the problem of swage disposal. If sewage is allowed to be emptied without treatment into the community source, the organic matter with its feeding bacteria soon renders these bodies of water unfit for drinking purposes as well as unfit for bathing or fishing. Unless this sewage is satisfactorily disposed of, it becomes a menace to the health of the neonle in the community.

There are several ways by which sewage, that is, human excreta and the waste waters of home, public buildings, and factories, may



Fig 9—Purifying Water by Aeration. When water is sprayed into the air what other factor besides oxygen enters into the killing of bacteria? What pathogenic bacteria are most likely to be killed?



Fig. 10—Contrast between fabrics washed in hard and in soft water. Upper view shows soum from hard water enmeshed in the fibers. How would surgical instruments be affected by washing them in hard water? Courtesy, The Permutit Co., N. Y.

be treated; the problem is to decompose the organic matter upon which the bacteria live, and kill pathogenic bacteria. In some disposal plants the diluted sewage is sprayed into the air in order to oxygenize the organic matter, and reduce the number of bacteria; in other plants the solid wastes are separated from the liquid by screening, sedimentation, and coagulation. This is followed by bacterial digestion in septic tanks prior to oxygenation, and subsequent chlorination. In the septic tanks (Imhoff) the organic matter is decomposed by the bacteria, which in turn are destroyed by one-celled animals called protozoa. By this treatment what was sewage becomes clear sterile water. The separated solid matter is incinerated, or used as a fertilizer.

### SELF-TESTING QUESTIONS

- 16 Of what does purification of water consist?
  - 17. What is distillation?
- 18 Why does boiling purify water?
- 19 Why does boiled water taste flat and how is this remedied?
  - 20. How may water be filtered in the home? 21. Describe the slow sand filter
- 22. Explain the rapid sand filtration method of purifying water
- 23 What does agration do to the water?
- 24 What is the preparatory process in the disposal of sewage and the
- return of waste waters to rivers and lakes?

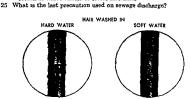


Fig. 11—Photomicrographs Indicating how water hardness affects hair. How may the resulting gummy residue be removed? Courtesy, Permutit Co. N Y.

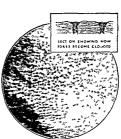
### IV. HARD WATER

## Objections to Use of Hard Water:

(1) It is the presence of certain mineral compounds in water which makes the water "hard." When soap is used in this water these minerals react chemically with the soap to form insoluble soaps that have no cleansing properties. They adhere to washed materials and cause them to become harsh and rough to touch. vellowish or gray in appearance, and to develop an unpleasant rancid odor when stored away (Fig. 10). This harshness is a very

undesirable condition especially if the cloth is to be in contact with tender or irritated skin. If iron salts are present, the materials may be discolored, a very objectionable feature in the laundering of clothes. In washing the hair in hard water the sticky, gummy feeling of the hair upon drying is due to these insoluble soaps (Fig. 11). In a somewhat similar way the pores of the skin become partially clogged from washing in hard water (Fig. 12) and in some cases this may produce skin irritations.

Fig 12—The Skin Washed in Hard Water This is an enlarged photograph of the skin of a gur's cheek. Observe the they pores which this magnification makes visible. Note the insertion Clagged pores may cause what? Courtesy, Permutit Co., N. Y.



- (2) In cooking with hard water, the lime salts form on the foods and harden them. Thus when peas and beans are cooked in hard water they do not soften sufficiently because the minerals in the water harden the legumin. In the making of broth and tea these mineral salts interfere with the process of extraction. Therefore, to produce the same strength of tea almost twice the amount must be used with hard water as compared with soft water.
- (3) When hard water is heated in boilers, certain mineral salts present become less soluble and deposit layers of hard scale on the sides of the boiler pipes (Fig. 13). Since this scale is a nonconductor of heat, it causes a great waste of fuel. The deposit in a teakettle consists of such lime salts.

### Water Softening:

Since there are many serious objections to the use of hard water several methods have been devised for the removal of the calcium

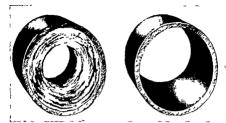


Fig. 13—Boiler Scale. Notice how the accumulation of the cement like scale cuts down the effective size of the pape. How does scale affect fuel consumption? Courtex, The Permuth Co. N. Y.

and magnesium salts which cause the hardness. There are two kinds of hard water, one, containing the bicarbonates of calcium and magnesium, is called temporary hard water; while the other, containing the sulfates or chlorides of these metals, is called permanent hard water. Temporary hard water gets its name from the fact that it may be softened by boiling, since heat changes the soluble bicarbonates into the insoluble carbonates of calcium and magnesium.

$$Ca(HCO_3)_2 \rightarrow CaCO_3 \downarrow + H_2O + CO_2$$
  
Insoluble

In actual practice it is more economical to precipitate these salts by the addition of a definite quantity of slaked lime

Permanent hard waters are softened by adding crude sodium carbonate.

$$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 \downarrow + Na_2SO_4$$

On a small scale in the home, washing soda ( $Na_2CO_3 \cdot 10 H_2O$ ), borax ( $Na_2P_1O_7 \cdot 10 H_2O$ ), and trisodum phosphate ( $Na_3PO_4 \cdot 12 H_2O$ ) are frequently used to soften water. In the reactions of all of the foregoing mentioned chemicals, the softening process de-

pends upon the change of soluble calcium and magnesium compounds into insoluble ones which are no longer able to act with the soap to prevent its lathering

Hardness of water, calculated as calcium carbonate, is measured in parts or "degrees" per gallon One degree is considered as 1 grain per gallon, and is equivalent to 0 017 Gm per liter, or 17 grain parts per million parts, or 17 ppm \* Each 1000 grains of hardness unites with and destroys about 1½ lbs of soap One thousand gallons of 10 grain water will destroy 15 lbs of soap which at 30 cents per lb would cost \$450

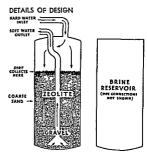


Fig 14—Zeolite Water Softener Water is filtered as it is softened Notice where the dirt collects. What expense is connected with the operation of this system?

## Permutit Process of Water Softening:

The water softening methods used in homes, laundries, hospitals, and small industrial plants have not been altogether satisfactory since they require close attention for their successful operation Within recent years this difficulty has been mostly overcome by the permutit process of softening hard water. This makes available for the home a water softener that is serviceable, effective, cheap, and easy to operate (Fig. 14). The chemical used in this process is natural sodium alumnum silicate, called zeolute, or the manufactured compound called Permutit, NaAlsSuOs, which for brevity

<sup>\*</sup>To change grains per gallon into ppm multiply by 17 and to change ppm into grains per gallon multiply by 0 0583

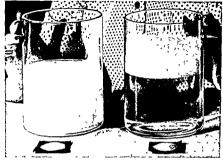


Fig 15.—Effect of Hard and Soft Water on Soop. The same amount of soop was added to these two containers. Notice how the hard water in the giasts to the left destroys soop, and how the soft water in the glass to the right makes a copious lather. What other compounds besides soop soften water? Courtesy, The Permitt Co. N. Y.

may be represented as Na<sub>2</sub>Z. When hard water filters through this material the undesirable calcium and magnesium ions are retained as calcium and magnesium zeolites, and the water is then "soft":

$$Na_2Z + CaSO_4 \rightarrow CaZ \downarrow + Na_2SO_4$$
  
Sodium Calcium

realite

After the Permutit has exchanged all its available sodium for calcium or magnesium, it may be automatically regenerated by allowing sodium chloride solution to filter through it.

The soluble calcium and magnesium chlorides are emptied into the drain and the Permutit is again ready for use. By this method it is evident that the only expense is the original cost of the softening unit and the sodium chloride needed for regenerating the zeolite.

Many of our hospitals and homes use this method of water softening

It is to be noticed that the Permutit process is an ion exchange method of softening water masmuch as the ions which cause hardness are replaced with sodium ions from the zeolite. Hence when water which has considerable hardness is softened in this way, the resulting concentration of sodium ion may make the water unsuitable for individuals on a low sodium diet.

In addition to the previously mentioned methods for softening water there has been introduced a chemical called sodium hexa metaphosphate (NaPO<sub>3</sub>)<sub>5</sub> This compound softens water by forming soluble complex ions with the calcium and magnesium ions present in the water. In this way the ions responsible for the hardness are effectively removed without the formation of any precipitates. Sodium hexametaphosphate is widely used in commercial and household water softeners. This type of softener is especially useful in cleaning laboratory glassware because it prevents film formation.

### **Exchange Resins**

The use of ion-exchange resins for water purification is more versatile than the Permutit method because not only calcium and magnesium ions, but also other ions, both positive and negative, can be removed

The exchange resins are synthetic organic substances, in some respects similar to plastics. They can be designed to perform rather specific functions such as removing all positive ions or all negative ions from natural water or solutions by the process of ion exchange. Use of combinations of resins makes possible a fairly complete deionization to give water which is as pure as distilled water. The ion exchange resins are also finding use for the removal of objection able ions in the preparation and purification of drugs, vitamins, etc. Lake the receive of the Permit Process, these resins can be regenerated after use

#### SELF-TESTING QUESTIONS

- 26 What are three main objections to the use of hard water?
- 27 What is temporary hard water and how may it be softened?
  28 What is permanent hard water and how may it be softened?
- 29 Explain the Permutit process of softening water
- 30 How does the use of the 10n-exchange resins differ from the Permutit process?

### V. PHYSIOLOGICAL IMPORTANCE OF WATER

The importance of drinking sufficient water so that there will be plenty for physiological purposes is clearly shown by reading the following paragraphs

### A Component of Protoplasm and Tissues:

We frequently think of foods as including only carbohydrates, fats, and proteins—the energy yielding materials, the substances needed for growth and repair of tissues. We may fail to realize that water too should be considered for the same reasons as foods. Water is as important as the foods we eat

Approximately two thirds of the body is composed of water. This includes the fluids in the active organs such as the liver, muscles and brain, and in the cells which contain a semiflaud called proto plasm. If these cells are to be normal and are to carry out chemical changes, they must not be allowed to become too dry. Under normal conditions the amount of water consumed daily amounts to about three or four liters, a large part of which is taken into the body with foods. Water is the medium in which many of the chemical changes in the body take place.

## A Component of All Body Fluids.

The blood is the circulating medium of the body for transporting nutrients, waste products, internal secretions (hormones), beat, and the phagocytes which fight invading pathogenic organisms. Normally, the percentage of water in the blood is constant, and if in sufficient water is supplied to the blood, the fluid is withdrawn from the tissues. As a consequence the cells suffer (dehydrate) at the expense of keeping the fluid of the blood constant.

Urine is the principal medium for the elimination of soluble waste products from the body. Whenever there is not enough water to dissolve and dilute the waste products, and allow them to filter through the kidneys, these organs cease to function properly and become damaged in attempting to eliminate highly concentrated waste solutions.

## A Tissue Lubricant

Water keeps most such surfaces as the mucous membranes of the eyes, nose, and throat, and thus prevents discomfort. It also mostens the joints, and acts as a solvent in the large intestines, thus admr direction and elimination.

## A Temperature Regulator:

You have learned that water has a greater capacity for heat than any other liquid or any solid. The body loses heat very slowly It is when the blood reaches the surface of the body that heat is lost. The blood with its high water content quickly equalizes temperatures as it circulates through the body. The regulation of the body temperature is mainly accomplished by the skin. Cold contracts the capillaries and does not allow much blood to reach the surface of the body. Heat, on the other hand, causes dilation of the capillaries and brings blood to the surface to be cooled. Heat also stimulates the sweat glands to produce more secretion and lower the temperature. Water then is necessary for perspiration.

## An Aid in Digestion:

Food is first dispersed and then acted upon by digestive fluids secreted by different glands. In both cases water is necessary Moreover, the greater the amount of water the more rapid will be the chemical action and absorption of the digested foods. Further more, water is one of the reacting substances during the actual digestion of foods and in many of the other changes which take place in the cells of the body. (See page 417)

From the previous statements it is evident that water is an important substance for maintaining life, and especially so when nutritive materials must be reduced to a minimum. Life without nourishment may continue for several weeks but without water death results in a few days.

#### SELF-TESTING QUESTIONS

- 31 Why is water important to the protoplasm of the cell?
- 32 Why is water an important part of the blood?
- 33 How does water affect the function of the kidneys?
- 34 State how water aids chemical activity
- 35 How does water regulate the temperature of the body?
- 36 Mention three ways in which water aids in the digestion of foods

#### SUGGESTED ACTIVITIES

- I THOUGHT PROVOKING QUESTIONS
  - 1 If steam is a colorless invisible vapor what is the material we ordinarily call steam?

- 2 What are three facts that make water especially suitable as the cooling liquid for automobile radiators?
- 3 What distinction is made between a mineral and a sanitary analysis?
- 4 How may a nurse quickly purify water contaminated by pathogenic organisms?
- 5 Name some metals that do not react with water
- 6 How is filtration carried out in your city?
- 7 What is the chief danger of a domestic filter?
- 8 Why is a cooling effect produced when a floor is sprinkled with water?
  - 9 What is formed when iron reacts with water?
- 10 What kind of impurities will filtration remove from water?
- 11 If you were camping out and suspected the water to be contain nated with typhoid fever germs how would you render it fit for druking purposes?
- 12 Name some foods other than those mentioned which contain con siderable quantities of water
- 13 Can water from its appearance or taste be judged as safe? Explain
- 14 What are the most desirable properties of water to be used for laundering? For drinking?
- 15. Pressure cookers subjected to superheated steam are made of aluminum and of steel. Why is steel not preferred?
   16 During the hardening process of plaster of Paris used in making a
- 16 During the hardening process of plaster of Pars used in making a surgical cast why doesn't the patient feel the chillness of the moist application?
  17 In using an ice bag for therapeutic purposes how much heat will
- be absorbed if the bag contained 200 grams of ice?
- 18 Temporary hard water contains calcium acid carbonate the calcium of which can be precipitated by household ammonia What calcium salt is precipitated?

#### II VOCABULARY TESTING OF NEW TERMS

specific gravity hygroscopic dutilistion specific heat deliquescent aeration heat of vaporization anhvárous temporary hard water permanent hard water anhydride heat of condensation heat of fusion mineral matter zeobte **bvdrate** organic matter Permutat protoplasm water of crystallization mineral analysis

efflorescent sanıtary analysıs

#### III. TOPICS FOR ORAL OR WRITTEN REPORTS

- 1 Water Purification in My Community.
- 2 Value of Soft Water in Reducing Costs and Improving Service
- 3 Methods of Water Softening in the Home
- 4 Progress in Treatment of Sea Water
- 5 Water Shortage in Urban Areas

### LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on pages 655, 657

# SOLUTIONS-LIQUIDS OF EVERYDAY USE

#### CHAPTER OUTLINE

- I SOLUTIONS, THEIR NATURE AND PARTS
  - (a) Meaning of the term "solu tions
  - (b) Components of a solution
- 17 Sermentery
  - (a) Conditions affecting solubility
    - (1) Nature of the solute and solvent
    - (2) The temperature
  - (3) The pressure (b) Saving time in making solutions
  - (c) Concentration of solutions (d) Ways of expressing exact concentration
- III THE PROPERTIES OF SOLUTIONS (a) Diffusion

- (b) Osmosis (c) Physiological saline solutions
- (d) Necessity of normal osmotic pressure
- (e) Boiling point and freezing point
- IV COLLOTHAL DISPERSIONS (a) Suspensions
  - (b) Colloidal dispersions
  - (c) Preparation of colloidal dis
  - persions (d) Classification of colloids
  - (e) Properties of colloidal
  - dispersions (f) Gels
  - V EMITERIONS

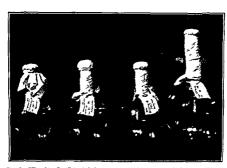
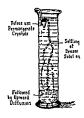


Fig 1-"The Big Four" in Solutions. Saline Solution, Ringer's Solution, Water, Dextrose What general precautions must be taken in making solutions? Couriery, University Hospital, Cleveland, Ohio

## I SOLUTIONS, THEIR NATURE AND PARTS

### Meaning of the Term "Solutions".

In a typical mixture such as powdered iron and sulfur, it is very easy to distinguish one particle from another, while in a compound, such as iron sulfide, every particle is alike in composition. Inter mediate between mixtures and compounds are the solutions. Like mixtures, they may be made variable in composition, while like mixtures, they may be made variable in composition, while like compounds they are uniform throughout. Everyone is familiar with the phenomenon of solution. Sugar or salt in water is a good example of a solution. If you drop a crystal of potassium permanga nate into a tall graduated cylinder containing water you may see the slow dissolving of the crystal with the formation of a clear purple color, which in time diffuses slowly through the water until uniformly distributed throughout the cylinder of water. If the



Fg 2—Solution in the Making The purple black crystals suspended in the paper st rrup just below the water surface slowly go into solut on. After the denser solut on settles what force causes of flussion upward?

solution is diluted it is possible to observe that all parts of the mixture appear exactly alike, i.e., it is a clear, homogeneous mixture Evidently there is a tendency for the particles of a substance in solution to distribute themselves uniformly throughout a solvent Such a process of dispersion is called diffusion and applies to gases as well as to liquids. From these statements a true solution is to be considered as a homogeneous molecular or ionic dispersion.

# Components of a Solution

In making up solutions water is generally used on account of its cheapness, accessibility, and its property of dissolving many sub stances. A water solution is often called an aqueous solution, while in an alcoholic solution the solvent is alcohol. As matter exists in three states solid, liquid, and gaseous, it is possible to form many different kinds of solutions by mixing one form of matter with another. In any solution the substance which is dissolved is called the solute, and that substance in which the solutie is dissolved is called the solvent, for example, in the solution of sugar in water, the sugar is the solute, and the water is the solvent. Water is the best of all solvents. Other common liquids that have great solvent power are alcohol, carbon tetrachloride (Carbona), gasoline (Energine), and either. It is quite essential that we choose the solvent which is most suitable for the purpose intended. For example, in removing grease spots from clothing we may use gasoline or carbon tetrachloride, if the spot is paint, we use turpentine, but if the spot is sugar, water does nicely

#### SELF-TESTING QUESTIONS

- 1 State three ways in which we are continually dealing with solutions
- 2 Why is solution of importance to the nurse? To the chemist? To the farmer?
- 3 What is a solution? Define the parts of a solution

### II. SOLUBILITY

## Conditions Affecting Solubility:

By far the most familiar type of solution is a solid dissolved in a liquid. For such solutions the extent of solubility of the solute depends upon

- (1) The Nature of the Solute and Solvent The nature of both the solute and the solvent has a very definite influence upon solution No material is absolutely insoluble Marble, for instance, will dissolve to a slight extent in water. Some substances which are but slightly soluble in water are readily soluble in certain other solvents. Greases and oils show practically no tendency to dissolve in water, but they are easily soluble in carbon tetrachloride, ether, gasoline, or trichloroethylene.
- (2) THE TEMPERATURE Generally when we wish to hasten the solubility of a substance we use heat, since the solubility of most substances increases with a rise in temperature On the other hand, a few substances decrease in solubility with a rise in temperature This latter condition may be clearly shown by boiling some clear linewater, which becomes turbid as a result of the separation of

some of the calcium hydroxide. The solubility of a solute usually is defined as the weight in grams of any solute that will dissolve in any gwen amount of solvent (usually 100 grams of water) at the given

#### SOLUBILITY

Substance	Weight dissolved by 100 grams of water			
District	0° C	20° C	100° C	
Sodium chloride	35 7	36 0	39 8	
Potassium nitrate	13 3	31 6	246 0	
Calcium hydroxide	0 185	0 165	0 077	

temperature A study of the above table shows that sodium chloride increases slowly in solubility with a rise in temperature while potassium nitrate (saltpeter) increases greatly. On the other hand note that calcium hydroxide (slaked lime) decreases in solubility. Most solids act like the potassium nitrate in their change of solubility with temperature. The solubility of gases in liquids is in general lowered by a rise in temperature.

(3) The Pressure This is another factor to be considered in solubility but mainly as applied to gases, as the solubility of gases increases with an increase in pressure (Henry 8 law) Thus in making carbonated drinks, the amount of carbon dioxide dissolved will depend upon the pressure as well as the temperature Varia tions in pressure do not affect the solubility of solids in liquids

### Savina Time in Makina Solutions

Sometimes it is desirable to hasten the process of solution of a solid, especially if there should be no unnecessary delay, such as in the preparation of a solution for a hypodermic injection. Time will be saved if the following suggestions are kept in mind

(1) Pounder the solid finely in order that as much surface as possible may be exposed to the solvent, for a solid dissolves at its surface only (2) Sur or agitate the mixture continuously, so that the saturated solution around the solid may be swept away and thereby allow fresh portions of the solvent to come in contact with the solid (3) Heat the liquid if necessary, that is, provided that heat does not cause any change in its chemical properties or introduce the danger of fire.



Fig. 3- To save time in making a solution

Concentration of Solutions:

When a solution contains a small amount of a dissolved material in proportion to the amount that could be dissolved, it is said to be dilute. When it contains a large amount it is concentrated; and when it contains all it can normally dissolve at a given temperature. it is saturated. As was mentioned in a previous paragraph, it is a general rule that the solubility of solids increases with rise in temperature and so at a higher temperature more of the solute will be in solution. Now if a solution saturated at a high temperature is allowed to cool to room temperature we might expect the extra amount of the solute to fall out of solution in the form of crystals as the temperature falls. This is generally the case, but sometimes when a hot solution is cooled slowly and is not disturbed, no solid immediately separates, even though the solution contains more solid than it can ordinarily dissolve at that temperature. This produces what is known as a supersaturated solution. Crystallization, however, will appear in time if such a solution is allowed to stand or is shaken, for example, often when jams or jellies are made, crystals of sugar slowly form after the material has cooled proving that the solution was supersaturated. Another familiar example of supersaturation often occurs when boiling down sugar to make thick fudge syrups and sauces. At such times avoid stirring, otherwise crystals of sugar collected on the sides of the pan during evaporation may be scraped off to cause more crystals to form, and thus produce a "grainy" consistency.

#### Ways of Expressing Exact Concentrations:

In using the term "concentration," we may be referring to one of several things, so it is well for us to keep in mind the conditions under which we use the term. In medicine, we commonly use the term percentage when referring to how much of the solute is in solution. This may refer to weight in weight, weight in volume, or

volume in volume Since one gram of water occupies essentially one milliter at room temperature, it is permissible, for convenience, to measure water by volume instead of by weight in preparing anieous solutions.

The use of per cent for expressing concentrations of solutions is widespread in hospital and pharmaceutical practice, hence some allustrations will be given A 4 per cent by weight glucose solution means that there are four parts by weight of glucose in one hundred parts by weight of solution. One would therefore prepare 100 grams of a 4 per cent by weight glucose solution by dissolving 4 grams of this sugar in 96 grams (or ml) of water

An important solution in hospital procedure is the physiological saline solution which is approximately a 0.9 per cent concentration of sodium chloride in water. To prepare 500 grams of this solution the technican would reson as follows.

0 9 per cent of 500 grams =  $009 \times 500 = 45$  grams Therefore use 45 grams of salt

500 grams -4 5 grams = 495 5 grams Hence use 495 5 grams (or ml) of water

The solution is then prepared by dissolving the salt in the water to give 500 grams of solution. Percentages calculated in this way are on a weight weight (W/W) basis

When both the solute and the solvent are liquids the volume volume (V/V) per cent is convenient to use because no weighing is necessary. The 70 per cent solution of alcohol and water used in the wards is in the proportion of 70 ml of alcohol made up to 100 ml with added water.

The chemist often expresses concentrations on a molar basis This shows the number of gram formula weights (moles) of solute present in one liter of solution A one molar (IM) concentration of sodium hydroxide NaOH, formula weight of 40 is prepared by dissolving 40 grams of this compound in sufficient water for one liter of solution Often concentrations other than one molar are more useful in practice, and one finds two molar (2M), one tenth molar (0 IM), etc

Chemists also employ normal concentrations when referring to the reactive ability of an acid, base, or salt solution A one normal solution contains one gram equivalent of the active radical per liter of solution For example, a one normal solution (IN) of any acid contains enough of that acid in a liter of solution to yield 1008 grams of replaceable hydrogen A one normal solution of a



Fig. 4—Measuring the Volume of a Solution. The volume of a solution can be measured to one hundredth of a mill ter by use of burets pictured here. Can you name some other pieces of laboratory equipment used for measuring volumes of solutions? Courtery Kimble Glass Company.

base contains sufficient base per liter of solution to provide 17 008 grams of hydroxyl, while a one normal solution of a salt contains as many grams of the negative radical per liter of solution as will react with 1 008 grams of hydrogen from an acid. Thus equal volumes of all solutions of the same normality are exactly equiva lent. Again, concentrations like 2N, 0 1N, and 0 01N, etc. are also used in actual practice.

Notice that molar refers to the concentration of moles of solute, whereas normality deals with the concentration of the active radicals of acids, bases, and salts Normal and molar solutions must never be confused, for though in some instances they are the same, in many cases they are quite different To illustrate, in the case of sodium hydroxide (NaOH) a molar and a normal solution are of the same concentration, but in the case of sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) a one molar solution is also a two normal solution. The following table will help to bring out these facts

	Formula	Grams per Liter in a	
Compound		Molar Solution	Normal Solution
Sodium Chloride	NaCl	58 44	58 44
Sodium Sulfate	Na <sub>2</sub> SO <sub>4</sub>	142 04	71 02
Hydrochloric Acid	HCi	36 46	36 46
Orthophosphoric Acid	H <sub>8</sub> PO₄	98 00	32 67
Sodium Hydroxide	NaOH	40 00	40 00
Barum Hydroxide*	Ba(OH) <sub>2</sub>	171 35	85 68

A modification of normality for expressing concentrations of very dilute solutions is the milliequivalent (mEq.) notation. This is particularly useful in clinical procedure for stating concentrations of electrolytes (ions) in body fluids and in parenteral fluids (See page 465). One milliequivalent weight is the one thousandth part of a gram equivalent weight. Thus one milliequivalent of sodium ion is 0 023 grams (23 milligrams). As an illustration, a container might be labeled 150 mEq of Na+ per liter.

#### SELF-TESTING QUESTIONS

- 4 What conditions affect the solubility of a solid in a liquid? The solubility of a gas in a liquid?
- 5 How may time be saved in making solutions?
- 6 How do you distinguish between the terms dilute concentrated saturated and supersaturated solutions?
- 7 What is a molar solution? A normal solution? Of an acid? Of a base? Of a salt?

<sup>\*</sup>In practice barrom hydroxide is not sufficiently soluble in water to make the concentrations given here

#### III. THE PROPERTIES OF SOLUTIONS

#### Diffusion:

As has been explained, the solute distributes itself uniformly throughout a solution. In the case of gases, we learned that the greater the pressure the greater the solubility. We can best understand diffusion by comparing it to this Evidently there is a pressure set up by a substance as it dissolves. As we know, pressures tend to equalize, and it seems that as a substance dissolves and sets up a pressure at the point of greater concentration, this pressure tends to equalize throughout the solvent by forcing the particles of the solute to all parts of the solution until there is a uniform concentration throughout the solution. This intermingling of two substances resulting from the motion of individual particles is called diffusion. Density markedly affects diffusion, and consequently liquids diffuse less readily than gases, while but few solids in contact with each other diffuse.

#### Osmosis:

Certain membranes will selectively permit solvent molecules but not solute molecules to diffuse through them. These membranes are found in plants and animals, and may also be prepared in the laboratory from cellophane, collodion, etc. Since they show a selective action they are described as semipermeable, or differentially permeable.

When two solutions of differing concentration are separated by such a membrane, the solvent molecules may pass freely through the membrane in both directions, but the solute particles are prevented from diffusing through the membrane from one solution to the other. The term osmosis is defined as the passage of solvent molecules through a semipermeable membrane from the solution of elesser concentration of solute into the solution of greater concentration of solute. Actually the solvent molecules diffuse through the membrane in both directions, but the rate of flow is greater from the more dilute solution. Thus both solutions tend to come to the same concentration. The force responsible for this flow of solvent, not fully understood by scientists, is termed osmotic pressure.

As an example, consider two sugar solutions, one a 2 per cent solution and the other a 5 per cent solution, separated by a suitable semipermeable membrane A film of collodion may be used

Osmosis will take place, and in a given time more water molecules will pass from the 2 per cent solution into the 5 per cent solution than will pass from the 5 per cent solution into the 2 per cent solution. Since the sugar molecules cannot diffuse through this membrane, the 5 per cent solution becomes progressively diluted by gaining water, and the 2 per cent solution becomes concentrated by losing water. If conditions permit, the two solutions will ultimately attain the same concentration, and are then said to be instance.

The principle of osmosis is very important in many physiological processes, such as the assimilation of nutrients, formation of urine, maintenance of blood volume and distribution of water. The principle is also applicable in many clinical treatments such as depletion of edema. Other interesting examples of osmosis are the passage of soluble mineral salts from the soil into plant rootlets, the rise of sap in trees, and the swelling of seeds during germination.

# Physiological Saline Solution

In the physiological salt solution the solute, sodium chloride, is present in approximately the same concentration as are the salts in the blood. In other words it is a solution that is approximately isotonic with the blood in regard to salimity. Practice and conditions vary what the concentration must be, but under normal conditions it is usually between 0.85 per cent and 0.9 per cent sadium chloride.

Ringer's solution, which is used in laboratory work, is supposed to contain the salts of the blood in exactly the same proportions as they occur in the blood

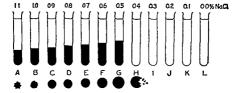
A physiological salt solution is used under the following conditions

- 1 When the body has lost much fluid, as in hemorrhage
- 2 Postoperative shock
- 3 When a septic condition exists, as in streptococcus infection
- 4 When a patient is debydrated and unable to take the necessary fluids by mouth

If the solution contains a greater percentage of salt than the blood, the solution is said to be hypertonic, while if it contains a lesser concentration it is said to be hypertonic. If the concentrations are the same, the term isotonic applies

# Necessity of Normal Osmotic Pressure

If placed in hypotonic saline solutions, the red corpuscles will begin to swell and finally rupture because of the water passing in through the cell wall by osmosis to dilute the more concentrated cell contents. This disintegration of the red corpuscles is called hemoly sis, and the blood is said to be laked. Hemolysis taking place after a salt infusion causes death. In a hypertonic salt solution, just the reverse process takes place, namely, the liquid flows out from the corpuscles, which then become shrunken or crenated, a condition called plasmolysis in plant physiology.



Fg 5—How hypertonic and hypotonic solutions injure cells. The solutions of NoCl in tubes C and D are about normal or physiological; that is they are usator with human blood. In them the red corpuscles retain the r normal shape and s xe. The hypertonic solutions in A and B however make the corpuscles shrivel while the hypotonic solutions E F and beyond make the corpuscles swell. In H in fact the swelling overtaxes the corpuscles and they rupture. Pure water represented in tube L as 0.0 per cent NoCl destroys red corpuscles and most other types of cells.

In case of drugs being administered intravenously, the effects ust described must be considered it oftentimes is necessary to dissolve the drugs in a physiological saline solution. In the cleanage of wounds, a sterile physiological saline solution is used not only on account of its mild antiseptic properties but also for the reason that the tissues are not changed by osmosis. Thus it is evident that solutions used in the body for therapeutic purposes should be isotomic to the blood, and intravenous and subcutaneous medications must be isotomic if red cells are not to be destroyed. However, because of quick oxidation, 10 to 50 per cent solutions of glucose are used intravenously without any apparent damage to the cells.

There are certain pathological conditions when it is advantageous to give a hypertonic solution. For example, in diseases accompanied by edema, frequently a concentrated solution of magnesium sulfate is given by mouth. In this way the high concentration of salt withdraws the fluid from the tissues into the intestine and eliminates it through the intestinal tract.

The food we eat is digested, passes into the blood by osmosis, and then is carried throughout the body. A familiar example of cosmosis is the condition which develops when the kidneys become diseased and fail to eliminate salt from their tissues. Too much fluid passes from the blood into these tissues, which then swell, giving rise to edema or dropsy.

# Effect of Solute on the Freezing and Boiling Points of Solvents:

Besides the property of diffusion, there are other physical properties of solutions due to dissolved substances. For instance, the boiling point of a solution of a nonvolatile compound is always higher and the freezing point is lower than that of the pure solvent. The extent to which this takes place depends upon the number of freely moving solute particles present in the solution. Advantage is taken of this latter property in the use of radiator-antifreeze mixtures, such as alcohol and water. The lower freezing point of a solution is indicated by the fact that the salt water of the ocean freezes only near the poles where the temperatures are very low.

Any crystalline substance, as it dissolves, will absorb heat. This is the principle in the use of salt to melt ice and snow, and in the use of ice-salt mixtures to obtain low temperatures.

#### SELF-TESTING OUESTIONS

- 8. What is the significance of osmosis?
- 9. What is the distinction between diffusion and osmosis?
- 10. What causes osmosis?
- 11. What is meant by a semipermeable membrane?
- 12. What importance is attached to the fact that cell walls are semi-permeable?
- 13. What is a physiological salt solution?
- 14. How is Ringer's solution made?
- How do you distinguish between the following terms: Isotonic, hypertonic, hypotonic, plasmolysis, laked, hemolysis?
  - 16. Under what conditions are isotonic salt solutions used?
    17. What causes the swelling associated with edems? With an insect bits?
  - 18. What change in physical properties of a solvent is produced by a solute?

### IV. COLLOIDAL DISPERSIONS

In the true solution the particles of the dissolved substance are too small to be seen, and they will never settle out Evidently the solute is dispersed as individual, fundamental particles, so that the true solution is a molecular or ionic dispersion (In the next chapter it will be learned that in some solutions the dispersed solute particles are electrically charged, and are called joins?

# COMPARISONS OF TRUE SOLUTIONS, COLLOIDAL DISPERSIONS, AND SUSPENSIONS

Properties	Molecular Dispersions	Colloidal Dispersions	Suspensions
Approximate diameter of particles in millimeters	1 10,000,000 mm to 1,000 000 mm	1 1,000,000 mm to 1 10,000 mm	1/10 000 to 1 mm
Visibility		With ultra microscope	With micro scope or naked eye
Osmotic pressure	High	Low	None
Relative size of molecule of hydrogen and the small est particle visible under the ultramicroscope, about 3,000,000 magnifi- cations	•		Too large to il lustrate here
Diffusibility and filtrability	Passes through membranes and filters	Passes through filters but not through membranes	Does not pass through filters or membranes

# Suspensions:

When particles of very finely divided clay or chalk are dispersed in water one observes a cloudy, milky effect If the mixture is allowed to stand, the dispersed particles will in time settle out and the liquid portion becomes clear The milky mixture obtained by the dispersion of the clay or chalk is referred to as a suspension Muddy water is another illustration of a suspension, if the water is permitted to stand the dispersed particles will settle to the bottom of the container The separation can be accomplished more quickly by filtering

#### Colloidal Dispersions:

Intermediate between true solutions and true suspensions, and merging into each, is a type of dispersion in which the particles are much too large for the true solution and yet too small for the suspension. Such a system, which normally never separates, is called a colloidal dispersion or, less correctly, a colloidal solution. The dispersed colloidal particles are either tremendously large molecules, like proteins, or they are aggregates of smaller molecules which can be viewed as clusters. Colloidal particles are in casseless, random motion when placed in a dispersing medium, yet it must be emphasized that the colloidally dispersed material and the dispersing medium are mutually insoluble.

In theory, and usually in practice, all solids and liquids, but not gases, can be treated to produce particles of colloidal size and these particles can then be dispersed in solid, liquid, or gaseous media to give colloidal systems. Since many solids and liquids (metal, acid, base, salt, carbohydrate, fat, protein) can be ground up and dispersed in liquids in which they are insolible, the study of this branch of chemistry becomes wide in its scope. The table on page 107 shows the eight types of colloidal dispersions

#### Preparation of Colloidal Dispersions:

The formation of colloidal particles may be approached in two different ways, namely, by dispersion methods and condensation methods. An illustration of dispersion methods is the use of colloid mills and homogenizers. These are machines used for breaking down substances by grinding, etc., to give particles of colloidal size. Also, certain insoluble substances are readily dispersed by the action of reagents which bring about disintegration or peptization into particles of colloidal size. Thus, the pepsin of the gastric fluid is effective in disintegrating protein food to give the colloidal peptiones. In fact, the disintegration of most foods is brought about through the presence of certain factors (enzymes) in the disease of the colloidal particles of the presence of certain factors (enzymes) in the

#### EIGHT TYPES OF COLLOIDAL DISPERSIONS

Dispersed	Dispersion Medium			
Substance	Gas	Liquid	Solid	
Gas (as bubbles)		Froths Foams as whipped cream, CO2 drinks		
Liquid (as droplets)	Fog as clouds, spray	Emulsions as milk, blood	Jeliy, gelatın	
Solid (as grains, films)	Smoke as fumes, dust	Gels as glue Cel lulose as lacquers cellophane, ray ons, plastics	Some alloys, colored glass, precious stones as topaz	

cles, and then finally into molecular dispersions, i.e., true solutions. The use of hot water on gelatin provides a further illustration of peptizing a solid to produce a colloid, in this case one which sets to a gel

Methods of condensation for the preparation of colloids are not common as those of dispersion. As an example, colloidal gold can be prepared by causing gold ions of a solution to come together and build colloidal clusters of gold atoms. Dispersions of colloidal gold in water have striking colors, the shade of color is dependent upon the size of particle.

#### Classification of Colloids:

For practical purposes it is convenient to classify colloidal dispersions which are liquids as lyophilic (solvent loving) and lyophobic (solvent-hating) Since water is so often the medium in which the colloidal particles are dispersed, the terms hydrophilic (waterloving) and hydrophobic (water-hating) are in common usage

In the hydrophilic colloids the dispersed particles have a great attraction for water and consequently this type of colloid is quite stable and generally more viscous than water itself Examples include starch, glues, gums, gelatin, pectin, and agar, all organic substances Other hydrophilic colloids appear as semisolids, and in this form are known as jells or gels Hydrophobic colloids are usually more difficult to prepare and are much less stable than the hydrophilic types. The dispersed particles of the hydrophobic colloid show little or no attraction for water, and for this reason such systems are mobile liquids which have about the same density and fluidity as water. The dispersed particles are usually inorganic in character as evidenced by such examples as colloidal ferric hydroxide, arsenic trisulfide, and gold and other metals. Hydrophobic colloids often appear to be true solutions, and therefore may be referred to as sofs as differentiated from solutions thus, a certain particle size of gold metal dispersed in water produces a gold sol which has the color and general appearance of a dilute potassium permanganate solution.

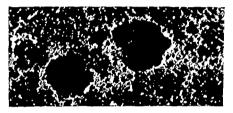


Fig 6—Electron M. croscope. Reflect ons of movements of collo dal particles by use of an electron microscope with a reveals 100 times more detail than is possible with the most powerful light microscope. The picture of these colloadal particles of s I ca show a magnification of 25 000 d ameters, the diameter of an average particle beling one millionth of an Inh. Courtery De Port Campany

## Properties of Colloidal Dispersions.

(1) Size of Colloids In general, the various properties exhibited by colloids stem from particle size As already noted, the dispersed particles of the colloid are exceedingly small, ranging in diameter roughly from 1 millimicron to 100 millimicrons (see table p. 105). A millimicron is one millionth of a millimeter. Colloidal particles, like solute particles (molecules ions) of a true solution, pass through filter paper, consequently, to remove colloidal particles, it is necessary to cause them to build up into larger aggregates which can precipitate. This can be accomplished in

various ways. Some colloids owe their permanency to the presence of a protecting agent, itself colloidal, and termed a protective colloid. Gelatin is an excellent protective colloid; used in the preparation of ice cream it surrounds the tiny colloidal particles and prevents them from growing and separating. Without the gelatin or some other protective colloid, ice cream would contain rather coarse crystals of ice and of sugar. Milk used for infant feeding may be made more digestible by adding a colloidal protecting agent such as gelatin, gruel, or dextrm to surround the colloidal casein particles and thus prevent the formation of too large curds.

One approach, therefore, in destroying a colloid is to remove or render ineffective any protective colloid present. Later it will be pointed out that colloidal particles are electrically charged. Removing the charge is usually an effective measure for bringing about precipitation.

(2) DIALYSIS: It has already been mentioned that colloidal particles, like the solute particles of the true solution, readily pass



Fig. X—Dualysis. How colloids are separated from crystalloids. Refinement and concentration of antitoxin substances by dialysis. Precipitated antitoxic material is placed in portament membranes and suspended in a current of frash water. Undesirable soluble salls pass through the membrane by dialysis, leaving the precipitated antitoxic substances within the membrane. In a optioning case, how could the poison be separated from the stomach contents? Courtery. Parke Dayes & Co.

through filter paper. However, a mixture of colloid and noncolloid (often termed a crystalloid) can be separated by placing the mixture in a parchment bag which is surrounded by water. The colloidal particles are too large to pass through the parchment, which serves as a membrane, but the molecules and ions of any dissolved substance diffuse readily through the semipermeable membrane. As an example, a mixture of starch and salt can be separated by this technique. This method of separation is called dialysis (di-al-i-sis). To dialyze, then, means to separate a crystalloid from a colloid by the diffusion of the crystalloid through a suitable membrane. Food, when colloidal, cannot penetrate the intestinal walls and enter the blood. The process of digestion produces crystalloids which are readily absorbed.

In this connection, with the general understanding that crystalloids pass readily through cell walls, while colloids are too large for this action, one must note that in the living organism there are other vital forces at work which may interfere with or modify the expected processes. That there is a difference between living and dead membranes is shown by the fact that sugar in solution will readily pass through a dead or parchment membrane, but will not pass directly from the intestine through the intestinal wall. Without doubt, osmosis plays an important part in the passage of body fluids and their dissolved substances.

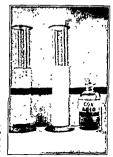


Fig. 8.—Colloidal Suspension of Sulfur. Colloidal sulfur is precipitated from a sodium thiosulfate solution by adding a few drops of add. What determines whether the colloidal particles will appear white or yellow?

- (3) Color The degree of dispersion, i.e., the fineness of the particles, determines the color of many colloids. Upon addition of a few drops of acid to a very dilute solution of sodium thiosulfate ("hypo") it is possible to observe after a few minutes a white colloidal sulfur, and then, after some time, as more free sulfur is formed, the color changes to yellow as the larger particles begin to precipitate (Fig. 8). Likewise, it is the colloidal material in the sky and in lakes reflecting and refracting the light rays that causes the blue color.
- (4) CHARGED PARTICLES Practically all colloidal particles in suspension are electrically charged. It is important to note that all of the particles of a given colloid will be charged positively or negatively. Consequently, the particles of a positive colloid attract those of a negative colloid and cause precipitation. The charges on a few common colloids are shown in the following table.

Positive	Negative
Albumin	Starch
Hemoglobin	Mucilage
Hydroxide of Fe Cu, Al	Silver chloride
Colloidal Pb Fe, Cu	Silicie acid
	Oil emulsion
	Indigo
	Prussian blue
	Most powders like charcosl and kaolin

Protein molecules, because of their comparatively enormous sizes, do not form true solutions, but instead behave as colloids when properly dispersed. For each dispersed protein there is a point of hydrogen ion concentration (pH, see p. 163) of the dispersing medium at which the particles of the protein will move neither to the anode nor to the cathode when placed in an electric field. This particular hydrogen ion concentration, expressed as a pH, is the isoelectric point of the protein in question. At this point the protein manifests minimum dissociation and dispersibility. Proteins are positively charged when dispersed in media more acid than their isoelectric points, and negatively charged in media less acid (more alkaline) than their isoelectric points. Therefore, the protein of egg albumin, which is negatively charged in alkaline

medium, will be precipitated upon the addition of a mercuric salt, the mercury providing positively charged ions.

Since all of the dispersed particles of a given colloid carry the same sign of charge they repel, and consequently a better dispersion and a more stable colloid are the result This explains why the addition of certain colloids to some of the medicinal preparations, such as the use of dextrin in the preparation of Petrogalar and emulsions of cod liver oil, rives more stable colloids.

(6) Absorption: One of the most characteristic and interesting properties of colloids is their ability to take up other substances (crystalloids or colloids) on their surfaces by a process called adsorption. It has been estimated that I ml. of solid material, when subdivided into particles of colloidal size, presents a total surface area of nearly 6,000,000 sq. cm. This property of the enormous total surface area of matter in the colloidal state of division is utilized in carbon-containing gas masks for adsorbing poisonous gases. It is this same property which accounts for the use of charcoal tablets in cases of indigestion. Gases and offensive odors are readily adsorbed by activated carbon and other colloids. Another good example of the adsorbing power of colloids is in the natural punification of water. The colloids of the soil retain the organic matter and the bacteria, and leave the water which drains through the soil pure enough to drink.



Fig 9—Adsorption. Surface adherence in the drying of one's face is an illustration of adsorption. Courtesy, H Armstrong Roberts, Philadelphia

The preparation of certain medicines is independent upon this property of adsorption, for example, some drugs which are insoluble in water can be dispersed in the presence of starch. The particles of the drug adsorb starch, and the starch then functions as a protective colloid.

#### Gels:

It has already been mentioned that many hydrophilic colloids can be prepared as gels, sometimes called jells or jellies dispersing liquid is retained by the colloid in much the same way that a sponge holds water. Freshly prepared soap is a colloid which has retained much water. A 1 per cent dispersion of gelatin in water will set to a semisolid. Some minerals, such as opals and agates, are dried jellies. Another example is pectin, a colloidal type of carbohydrate found in unripe fruit, which serves to form the supporting structure in making food jellies. In our homes we have seen these gels in custards, and in cornstarch and gelatin desserts. Frequently, gels, for example custards, will shrink upon standing and squeeze out a part of the liquid, a process called syneresis The drying of a blood clot (gel) with the discharge of serum is an example of syneresis. It must not be thought that water is the only liquid used for the dispersion of colloidal matter. The alcohol and glycerin used by the pharmacist and the cosmetician are examples of other liquids employed in the preparation of many colloidal dispersions and gels.

Many of the tissues of the body are highly hydrated and should be considered as gels The protoplasm, which is the fundamental material of the cell, is colloidal and exists as  $a \in I(\mathbb{F}_2, \mathbb{I}_2)$ . The



Fig. 10—Protoplasm is a Gel. The colloid protoplasm exists as a gel in the cells of the body. Why is the body able to hold so much water?

high degree of hydration of the colloidal substances in the cell accounts in large part for the fact that two-thirds of the weight of the body is water. Even the enzymes (en'-zims) which function as catalysts in body chemistry are colloidal in character. As stated, the proteins, which constitute the greater part of the tissues, possess the property of taking up water \* This phenomenon is called mibbition (just the opposite of synersis) Especially is this evident in the presence of acids and bases. Consequently, in diseased conditions of the body when acids are formed the tissues "swell" or adsorb an abnormal amount of water. In the action of a muscle the lactic acid which is produced stimulates changes in the water content. It is only when the lactic acid is removed that the muscle fiber returns to normal. Any local accumulation of acid in the tissues, such as resulting from a bee sting, causes excessive adsorption of water, thereby producing swelling or local edema.

The importance of colloid chemistry is better appreciated when we learn that animal and plant tissues are colloidal in structure that our food passes into colloidal condition, and that colloid chemistry is closely related to cooking, baking dyeing, and sewage disposal In some areas of study and research we are just beginning to realize and appreciate the far reaching implications and applications of this branch of chemistry.

#### V. EMULSIONS

If water and a little oil, two substances that do not mix, are shaken together, small globules of the one remain suspended in the other for some time, and the result is a liquid, milkly in appearance. This kind of dispersion is called an emidsion. However, the two liquids soon separate. If a colloidal substance insoluble in both of the liquids is added before shaking, a more permanent emilision results. The insoluble colloid, called an emilisifying agent, here acts as a protecting colloidal agent, i.e., it forms films around the oil droplets, which prevent them from running together. A few drops of a soap solution will make a permanent emilsion of oil and water Salad dressing, for example, mayonnaise, is an emilsion of oilve oil and vinegar, made permanent by the colloidal yolk of an egg Milk is an emilsion of butter fat in water, with albumin and casein serving as the emilsifying agent. An emilsion of col liver oil is often used medicinally.

The emulsification of the fats in foods by the bile is of great physiological importance since this aids digestion. Carron oil, which is used for burns, is an emulsion of linseed oil and limewater

<sup>\*</sup>Within recent years the water adsorbed by proteins and other classes of compounds as an integral part of tissue has been referred to as bound water. It has a special studies on resisting desiccation

The oil is soothing, while the limewater neutralizes the acid formed when the skin is burned. Burns are dangerous because of the loss of proteins by oozing from the burned area and the destruction of the tissues to form poisons which enter the general circulation (See page 779)

# SELF-TESTING QUESTIONS

- 19 What is a suspension?
- 20 What does colloidal chemistry deal with?
- 21 Why do colloids have special properties?
- 22 What four characteristic properties do all colloids possess?
- 23 Define and illustrate dialysis
- 24 What is a crystalloid?
- 25 Why are colloids used in many pharmaceutical preparations?
- 26 What is a gel?
- 27 What is an emulsion?
- 28 How are emulsions made permanent?

#### SUGGESTED ACTIVITIES

- I THOUGHT PROVOKING QUESTIONS
  - 1 How does a solution compare in composition with mixtures and compounds?
    - 2 What is the necessity of drinking water?
  - 3 The boiling of meat to make broth is based upon what facts?
  - 4 Why should a physiological saline solution be made correctly from an osmotic standpoint?
  - 5 Given an apparent solution how could you prove whether it was a true solution or a colloidal dispersion?
  - 6 In what ways are solutions important?
  - 7 What is the difference between osmosis and dialysis?
  - 8 How are emulsions made permanent? Explain using an example 9 From a colloidal standpoint explain the preparation of cake
  - frosting

    10 How are the properties of a liquid modified by dissolving a substance in it?
  - 11 Explain the reason why a dried prune when placed in water gradually swells to the original size of the fresh fruit
  - 12 Would there be a difference between dead and living membranes with regard to the extent of osmosis? Illustrate
  - 13 In boiling meats why does the addition of a little acid such as vinegar or tomato juice make them more tender?
  - 14 How would you expect colloidal dispersions to differ from true solutions in respect to osmotic pressure?
  - 15 In what respect may blood be considered to be a solution? May it be considered to be a colloid? Explain
  - 16 Why does a chemist prefer solutions made up on a molar or normal basis rather than on a percentage basis?

- 17 One liter of a normal saline (NaCl) solution contains how many grams of salt? How many times stronger is this solution than a physiological saline solution?
- 18 One liter of 0.5M hydrochloric acid contains how many grams of hydrochloric acid?

п	Vocabulary Testing of New Terms			
11	solution solvent solute dilute concentrated saturated supersaturated comosis	sempermeable sotonic hypertonic hypotonic hemolysis laked plasmolysis suspension	colloid colloidal dispersion peptization dialysis crystalloid isoelectric hydrophilic	adsorb gel imbibition emulsion physiological saline solution syneresis hydrophobic

# III Topics for Oral or Written Reports 1 How Soil Purifies Water

- 2 The Importance of Osmosis in Plant Life and Growth
  - 3 Some Solutions Commonly Used in Hospitals

#### LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on pages 659 663

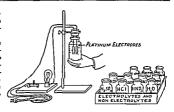
# IONIZATION - THE EXPLANATION OF CHEMICAL ACTION IN SOLUTION

#### CHAPTER OUTLINE

- I. SOLITIONS CONDUCTING ELEC-TRICETY
  - (a) Testing conductivity of solu- IV CHEMICAL ACTION IN SOLUTION
  - (b) Acids, bases, and salts-electrolytes
  - (c) Effect of dissolved substances on the freezing point, boil ing point, and on osmotic pressure
- II IONIZATION THEORY:
  - (a) Ions
    - (b) Chemical activity of electro-
- III ELECTRON EXPLANATION OF ION-
  - IZATION (a) Crystals contain ions
  - (b) Difference between 10ns and
  - (c) Ionization is represented by reversible reactions
  - (d) Why nonelectrolytes are nonconductors

- (e) Ionization explains electrolysis
- (a) Effect of dilution on ionization
- (b) Strong vs weak acids (c) Strong vs concentrated acids (d) Ionization in the fluids of the
- body (e) Newer concept of acids and hasee
- V. IONIC REACTIONS
- (a) Tests for 10ns (b) Preparation of an insoluble
  - substance (c) Reactions which go to
  - completion (d) Value of the ionic theory
- VI STAINS
  - (a) Stam removal methods
  - (b) Stam removal (c) Wet and dry cleaning (d) Ousting the clothes moth

Fig 1—Testing for Conductivity. Apparatus for testing the conductivity of a solution Note-If dry cells are used as a source of airrent an ammeter will be found to be more sensitive than an incandescent tamp to small currents. Why are the electrodes usually made of platinum?



# I. SOLUTIONS CONDUCTING ELECTRICITY

# Testing Conductivity of Solutions:

When two copper wires leading from the positive (anode) and negative (cathode) terminals of a battery are connected, an electric current flows through the circuit thus made. If an incandescent lamp is connected into this circuit, the glowing of the lamp indicates that a current is passing through the circuit. With this arrangement it is possible to test the conductivity of various solutions (see Fig 1) If the two electrodes (terminals of the wires) leading from the battery are placed in distilled water and in solutions of such diverse compounds as salt, hydrochloric acid, sodium hydroxide, alcohol, and sugar, the lamp in the circuit will hum brilliantly in the solutions of salt, hydrochloric acid, and sodium hydroxide, but it will not light in the distilled water, in the solution of alcohol, or in the solution of sugar in water. This means that the solutions of salt, hydrochloric acid, and sodium hydroxide are good conductors of electricity Before any deductions are made from these experiments attention should be called to the fact that as the current is passing through these latter solutions, bubbles of gas are being formed This is an indication that some chemical change is taking place A change of such a nature involving the decomposition of a substance by means of the electric current is called electrolysis

# Acids, Bases, and Salts-Electrolytes

From these experiments we learn that solutions of different substances in water vary in their power to conduct an electric current Substances which conduct an electric current are called electrolytes (Greek electron, electricity + lysin, a splitting = electric splitting), while those which do not carry a current, such as sugar, are called nonelectrolytes

Electrolytes	Nonelectrolytes
(Conductors)	(Nonconductors)
Acids	Pure Water
Bases	Alcohol
Salts	Sugar

Since the fluids of the human body contain acids, bases, and salts, it may be readily understood why it is dangerous to come un contact with any source of electric current. If one stands in water, or even in a damp place and makes contact with some source of electricity, such as an electric switch, or the handle of an electric rom, it is often possible to get a "shock". This shock is due to the electricity which passes through the solution of electrolytes in the human body and then by way of the minerals in the water to the ground.

An interesting and practical application of the conductivity of electrolytes in body solutions is the use of the electrocardiograph (Fig. 2), an instrument used by the physician for measuring variations in the electric current released during the contraction and relaxation of the heart.

To obtain a record of such a feeble current it is necessary to make a very close contact between the body and the instrument. This is obtained most commonly by using an electrode jelly (salt, powdered

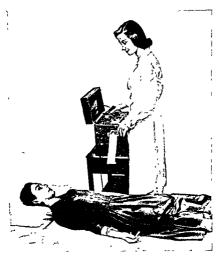


Fig 2—Ionization Makes This Possible. A direct-writing electrocardiagraph, which produces on immediate record of the heart's action for the physician, eliminating darkroom bother and delay, hitherto necessary on the old-type photographic electrocardiagraphs. What importance is attached to variations in the cardiac cycle? Courtery, Sonborn Company.

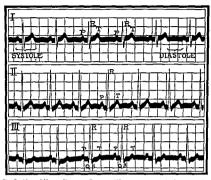


Fig 3—Normal Human Electrocordiagram. Waves are seen only during systole, when either the other or the ventriles are controcting, when the heart is quescentiale are controcting, when the heart is quescent in disable, waves are obsent. The record consist of 3 ports or more called it leads." The patients right hand, leth nod, and left not or acconsected with the instrument by separate waves, which are used successively in poirs. Lead I, Righth hand and left foot teed III, Leth hand and left foot lead III, leth hand and left foot lead III leth hand and left foot led III leth hand and left in the constant of the control of the contr

pumice, gum, etc.) between the electrodes placed over an artery on each arm and left leg, or various positions on the chest, neck, etc.

The purpose of the discussion thus far in this chapter has been to point out that one class of dissolved substances (nonelectrolytes) does not conduct an electric current, while the other large class of soluble compounds (electrolytes) does allow electricity to pass through its solutions

Effect of Dissolved Substances on the Freezing Point, Boiling Point, and on Osmotic Pressure:

We have learned in the preceding chapter that substances like sugar and salt, when dissolved in water, will lower the freezing Ionization 121

point and raise the boiling point of the water. Experiment has shown that the magnitude of the freezing point depression and the boiling point elevation is directly proportional to the number of solute particles in a given quantity of colvent. Osmotic pressure values are similarly dependent upon the concentration of solute particles. As an example, 10 grams of sugar dissolved in 1000 grams of water will produce twice as much change in the freezing point, boiling point, and osmotic pressure as 5 grams of sugar in the same quantity of water.

All nonvolatile nonelectrolytes are equally effective Cane sugar (C12H22O11), glycerin (C2H2O2), and urea (CO(NH2)2) are non electrolytes and have gram molecular weights of 342 grams, 92 grams, and 60 grams respectively. If one prepares solutions by dissolving a gram molecular weight (one mole) of each of these nonelectrolytes in 1000 grams of water, it will be found that for all three the freezing point of the water is depressed by the same amount, namely 185° C Also, the boiling point of the water is elevated by 0.52° C, and the osmotic pressures developed by the solutions are the same. The reason for this identical behavior of the nonelectrolytes becomes clear from Avogadro's law, which states that gram molecular weights of all nonelectrolytes contain the same number of molecules Notice that these effects do not depend upon the kind of dissolved particles, or upon their weight. but only upon the number of particles Thus 342 grams of cane sugar (one mole) and 60 grams of urea (one mole) contain the same number of molecules

In the case of electrolytes, when compared to nonelectrolytes, the changes produced in the freezing point and the boiling point of water are more marked. Thus, a grain formula weight (one mole) of sodium chloride, 58 5 grains, when dissolved in 1000 grains of water, lowers the freezing point and elevates the boiling point by amounts almost twice those produced by nonelectrolytes. In order to explain the abnormal behavior of electrolytes in solution, as compared to nonelectrolytes, and to account as well for a number of other important properties of electrolytes, for example, electrical conductivity, an ionization theory has been developed.

#### SELF-TESTING QUESTIONS

- 1 What is an electrolyte?
- 2 What classes of substances are electrolytes?
- 3 Why may you get an electric shock?

- 4 How is common salt used in electrocardiograph work?
- 5 What three effects in the properties of solutions are produced by dis solved substances?

  A charge in the properties of a solution of a product solution
- 6 A change in the properties of a solution of a nonelectrolyte is due to what?
- 7 What is a gram molecular weight?

#### II. IONIZATION THEORY

lons.

It has been pointed out that all nonelectrolytes when used in the same concentrations have the same effect in depressing the freezing point and elevating the boiling point of water, and in developing osmotic pressures Also, the magnitudes of these effects are determined solely by the number of particles in solution. Since electrolytes produce greater changes than nonelectrolytes, it is evident that one gram formula weight (one mole) of an electrolyte must provide a greater number of particles than does one gram formula weight (one mole) of nonelectrolyte must provide in mole) of a nonelectrolyte must provide a greater number of particles than does one gram formula weight (one mole) of a nonelectrolyte must

Sodium chloride, NaCl, is a typical electrolyte, and it has been already stated that this substance is an iomic compound, i.e., the fundamental particles of structure are sodium ions and chloride ions. Therefore, a water solution of sodium chloride contains no molecules of the salt, but, instead, wandering sodium ions and chloride ions are present. The total number of ions in one mole of sodium chloride is twice the number of molecules in one mole of any nonelectrolyte. If one dissolves one mole of sodium chloride in 1000 grams of water, it would be expected that the solution would freeze not at -185°C, but at twice this value, or -37°C. By experiment the freezing point is found to be -33°C, not quite as low as to be expected. This is due to the fact that the ions, particularly in the more concentrated solutions, are not entirely free to act as individual, unhampered particles. The word ion is derived from the Greek language, and means "wanderer".

The following ionic equation brings out the fact that a gram formula weight of sodium chloride provides twice as many particles as a mole of any nonelectrolyte

Sodium hydroxide, like sodium chloride, is an ionic compound

Sulfuric acid is a water solution of a molecular type of compound,

called hydrogen sulfate, H-SO<sub>4</sub> In water this compound ionizes in two stages

H<sub>2</sub>5O<sub>4</sub> 
$$\rightleftharpoons$$
 H<sup>+</sup> + HSO<sub>4</sub><sup>-</sup>

Molecular compound Ion Esulfate ion

HSO<sub>4</sub><sup>-</sup>  $\rightleftharpoons$  H<sup>+</sup> + SO<sub>4</sub><sup>-</sup>

Sulfate ion

The double arrow indicates that the reaction is reversible, i.e., two opposing processes are going on at the same time, and consequently both ions and molecules will be present as solute particles. Seldom do all of the molecules in solution dissociate into ions

Ions are electrically charged particles, and may be charged atoms, or charged groups of atoms called radicals. The number of charges on an ion corresponds to its valence. It is the ions which carry the electric current between the poles, or electrodes, in solutions of electrolytes. Ions, regardless of type, have the same effect on the freezing point, boiling point, and osmotic pressure as do molecules. Notice again, it is the number of solute particles, not kind, that determines the magnitudes of these three properties of solutions.

# Chemical Activity of Electrolytes:

From the previous paragraphs it is to be noted that electrolytes are of two broad classes, those which in pure state are ionic compounds (sodium chloride, potassium nitrate, sodium hydroxide, etc), and those which are molecular in character, but which dis sociate to varying degrees in water to give ions. For the latter it must be understood that the ionization is caused by the solvent. usually water, and not by the electric current. The discussion at the beginning of this chapter was used to show that some solutions conduct the electric current by reason of the ions moving in an orderly direction between the two electrodes. Some molecular compounds ionize more completely than others, and water is con sidered the best ionizing solvent. In a concentrated solution the molecules of such an electrolyte are close together and unable to dissociate into a great many ions because there is always a tendency of the ions to unite and form molecules Consequently, dilution aids ionization up to a certain point because in dilute solutions the ions meet each other less frequently as they wander about and are

<sup>\*</sup> The extent of ionization depends not only on the solution but also upon the physical state for example melted NaCl, but not solid NaCl can be electrolyzed. The tempera ture also affects ionization, since some gases are ionized at high temperatures

less apt to unite to form molecules Since chemical reaction is greater between ions than molecules dilute solutions bring about chemical changes more rapidly and completely Many compounds which ionize readily in water do not ionize when dissolved in other liquids

From a physiological standpoint the action of the different ions is of great importance in the life processes of the body. It is the ions of dissolved electrolytes that produce osmotic pressure in the cells and thereby regulate body functions. In the blood it is the ions of calcium on the one hand, and the ions of sodium and potassium on the other, which account for the contracting and relaxing of the heart muscle. The general functions of inorganic ions in the living body tissues are to (1) contribute to the building and repair of tissues, (2) influence the contraction of muscles and uritability of nerves, (3) help maintain the osmotic conditions, (4) be largely responsible for the acidity and alkalinity of digestive juices, and (5) insure normal chemical reactions.

#### SELE-TESTING QUESTIONS

- 8 What is an ion?
- 9 How does the electric charge on an ion compare with its valence?
- 10 What produces the freely moving ions?
- 11 How does the effect produced by a molecule in solution compare with the effect produced by an ion in solution?
- 12 Why is it generally better to work with a dilute solution?
- 13 Illustrate by an example the meaning of a nondissociating liquid
- 14 In solutions of electrolytes what are the reacting particles?
- 15 What are the various functions of the ions in the body cells?

#### III ELECTRON EXPLANATION OF IONIZATION

#### Crystals Contain lons

How does the electron theory explain the formation of the ions of sodium chloride? From a study of the original atoms of sodium and chlorine (Fig. 4) it may be noticed that when the outer shell. or

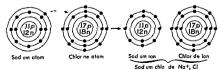


Fig. 4—Formation of Sadium Chloride. Eight electrons in the outer shell produce a satisfied or stable condition.

Ionization 125

valence electron, of the sodium atom moves over to the chlorine atom, the sodium atom is left with an extra positive charge and consequently becomes a sodium ion. Na+ At the same time, the gain of an electron by chlorine makes the chlorine atom become a chloride ion. Cl- The sodium chloride formed has a stable electron structure, there being eight electrons in the outer shell of each ion Compounds like sodium chloride formed by an exchange of electrons are often called ionic compounds. From this it is evident that crystalline sodium chloride is in reality made up of sodium ions and chloride ions, which are held together by their electrical attraction This type of valence holding the ions of electrolytes together is called electrovalence Similarly, all crystalline electrolytes are com posed of ions, and therefore it is not necessary to dissolve crystals to get ions It is only when crystals are dissolved in some dissoci ating liquid as water, or melted, that the valence forces are overcome, and the ions are free to move about

#### Difference between lons and Atoms:

As just stated, when the outer shell of an element is completed, that is, when there is no tendency to lose or gain electrons, the atom become stable. In other words, chemical activity is then greatly reduced. Examination of the diagram of the sodium ion shows that a stable condition of eight electrons exists in the outer shell. This may explain why the sodium ions are inactive in water, transparent, and nonpoisonous, while the sodium atoms react vigorously with water, and are poisonous. At first thought, it is hard to inderstand why the properties of an atom differ so much from the properties of an ion. However, the chemical activity of an element is measured in terms of the ability of its atoms to gain, lose, or share electrons. Chlorine, for example, is reactive because each of its atoms has a great affinity for an electron to complete and stabilize the outer shell.

# Ionization Is Represented by Reversible Reactions:

We may now have some idea of the behavior of an electrolyte when in solution. The following equations show the ionization or the dissociation of typical acids, bases, and salts

# Sali Na+Cl- Na++Cl-

The double arrows in the first two equations indicate that the differ ent kinds of ions reunite when water is removed. Not all of the molecules ionize and consequently there are both positive and negative ions and undissociated molecules present. As the ions and molecules move about in solution some of the positive and negative ions unite to form molecules, while other molecules are dissociating into ions. Soon, however, an equilibrium is reached, and the percentage of ions and molecules in the solution remains constant. Such reactions, which can go in either direction at the same time, are called reversible reactions. It will be noticed again that the number of electric charges an ion bears is the same as the valence. Also, it is noticeable that some compounds, like H<sub>2</sub>SO<sub>4</sub>, form more than two ions, and ionize in stages.

Both sodium hydroxide (NaOH) and sodium chloride (NaCl) are onne compounds. In water the ions of these crystalline solids are pulled apart and become free to move about Occasionally, particularly in the more concentrated solutions, ions of opposite charge collide and form what might be called a "cluster" of ions. In the examples used here the simplest clusters would be (Na\*, Cl-) and (Na\*, OH-). In the clusters the charges become more or less satisfied hence in this form the ions have a reduced chemical activity. In equations of ionization, where the solute is an ionic compound, the double arrow signifies equilibrium between free ions and ion clusters.

#### Why Nonelectrolytes Are Nonconductors

The question might well be asked, "Why do nonelectrolytes not ionize" Thus far in this chapter we have been concerned with loss or gain of electrons to give ions. Atoms can also share electrons with each other, so that both acquire complete outer shells. It has been stated repeatedly that several gaseous elements exist as two atoms per molecule (O<sub>2</sub>, H<sub>2</sub>, Cl., etc.) In the case of the chlorine molecule (Fig. 15, p. 20), each of the two atoms shares one of its electrons with the other, and in that way completes the orbit of each, thus forming a molecule of chlorine. This type of valence holding the atoms of nonelectrolytes together is called covalence, and the compounds are known as covalent compounds.

The atoms of a compound radical are held together by covalence, and consequently radicals do not separate into individual ions as can be noticed in the case of sodium hydroxide

$$N\alpha \xrightarrow[bond]{bond} O \xrightarrow[bond]{covalent} H \rightleftharpoons N\alpha^+ + -O \xrightarrow[bond]{covalent} H$$

$$[onic compound] on [on (rad cal)]$$

When shared electrons belong as much to one atom of an element as another, it is impossible to form ions, consequently, we conclude that nonelectrolytes may dissolve, but not ionize, because of the sharing of electrons. This property of atoms of nonelectrolytes to share electrons further helps us understand why nonelectrolytes are chemically less active.

Since valence depends upon the number of electrons in the outer shell of the atom, a briefer method of showing shared electrons is to drop the inner shells, write the symbols of the atoms, and surround the symbol of each atom by paired dots. Each pair of dots then cor responds to the number of pairs of electrons shared, and each pair represents a valence of one. The chloring atom is indicated as

CI

The chlorine molecule which contains two atoms with the two atoms sharing a pair of electrons, and each atom having six un shared electrons to complete its orbit, is represented as

CI CI

The diagrammatic formulas of the following nonelectrolytes, CH<sub>4</sub>, CO<sub>2</sub>, and CH<sub>3</sub>OH further show how shared electrons exist between the respective atoms of covalent compounds

H C H The carbon atom in CH<sub>4</sub> shares four pairs of electrons with the four H atoms to form a molecule of methane, and has a valence of four

Cerbon

Carbon

H C O H electrons, three with the three H atoms and one with the O atom Another pair is shared between the O atom and the H atom attached to it

It must not be concluded that all of the molecular structures which result from atoms sharing electrons are nonelectrolytes When electron pairs are not reasonably equally shared by atoms in molecules the molecules are polar, and varying degrees of ionization will take place in water. Thus hydrogen chloride, a gas, con sists of molecules in which the hydrogen atom and the chlorine atom share a pair of electrons. The sharing is not equal, however, since the chlorine has a greater affinity for electrons than does hydrogen. When the hydrogen chloride is dissolved in water, the hydrogen is pulled away from the chlorine the pair of electrons staying with the chlorine, this produces ions.

# Ionization Explains Electrolysis

You have learned that when an electric current is passed through a solution of an electrolyte, chemical action takes place. Now we shall see how the ionization theory helps us understand reactions that take place in solution. It will be remembered (page 124) that when sodium and chlorine unite, the sodium loses an electron (5) to the chlorine, thus the sodium atom becomes an ion with a positive charge and the chlorine atom an ion with a negative charge. These oppositely charged ions are held together by mutual attraction and form electrically neutral sodium chloride, however, upon being dissolved in water, the force holding the ions together is overcome, and they separate to wander around in solution,

the chlorine retaining the electron received from the sodium atom. The sodium ion is then positively charged and the chloride ion is negatively charged. The water present is also ionized only to a slight degree however, as expressed in the following equation

When the current of electricity is passed through this solution both the H<sup>+</sup> and Na<sup>+</sup> are attracted to the cathode (negative electrode) Since the H<sup>+</sup> is more easily discharged than the Na<sup>+</sup>, each H<sup>+</sup> takes up an electron and becomes a hydrogen atom

$$H^+ + \epsilon \rightarrow H^\circ$$

The hydrogen atoms pair off as molecules to produce hydrogen gas

In a like manner the negatively charged OH- and Cl- are attracted to the anode (positive electrode) where the chloride ion which is the more easily discharged of these anions gives up an electron to form a chlorine atom:

The union of chlorine atoms forms molecules of chlorine; these then dissolve in the solution to some extent, but largely escape as a gas.

The accumulation of Na<sup>+</sup> and OH<sup>-</sup> in the solution as the electrolysis progresses provides sodium hydroxide (lye) which is another product of the electrolysis of sodium chloride solution. The electrolytic process which has been described is an important commercial method for the manufacture of chlorine and sodium hydroxide. The hydrogen which is produced may be burned in the chlorine to obtain hydrogen chloride for the preparation of hydrochloric acid.

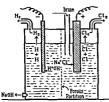


Fig. 5—Electrolysis of Brine. Diagram illustrating the theory of electrolysis of an NaCl solution. What three important products are obtained?

Other examples of equations for ionization and electrolysis follow:

I. Ionization: H<sub>2</sub>SO<sub>4</sub> → H<sup>+</sup> + H<sub>5</sub>O<sub>4</sub>-

II. Electrolysis of water which contains a little sulfuric acid-

a. At the cathode ( - )  $H^+ + \epsilon \rightarrow H^\circ$ 

then

2 H° → H<sub>2</sub>↑

b. At the anode ( + )  $OH^- \rightarrow OH^\circ + \epsilon$ 

then

4 OH° → 2 H<sub>2</sub>O + O<sub>2</sub>↑

The hydroxyl ion is more readily discharged than the sulfate ion hence in the electrolysis of extremely dilute sulfuric acid only water is decomposed

I Ionization Cu++SO - - Cu++ + SO -

II Electrolysis

a At the cathode ( - )  $Cu^{++} + 2\epsilon \rightarrow Cu^{\circ}$ 

b At the anode ( + ) same as b, on p 129

In the electrolysis of copper sulfate solution, the copper deposits on the cathode If copper electrodes are used copper is taken from the anode into solution as copper ion

This transfer of copper metal from the anode via the solution to the cathode explains the general principle involved in electroplating, and electrorefining of copper

From the foregoing explanations it is evident that electrolysis is a process in which an electrolyte in solution is chemically changed by the energy of the electric current

#### SELF-TESTING QUESTIONS

16 What is a valence electron?

17 What is a stable electron structure?

18 Are ions present in crystalline compounds?
19 What two conditions will liberate ions of an electrolyte?

20 When is an element inactive?

21 How can you account for the difference in the properties of an atom and an ion? What is a reversible reaction?

22 In chemical reactions when do atoms form covalent compounds?

23 Why do not some compounds ionize?

24 Why are certain covalent compounds not very active in solution? 25 What is the meaning of pair of electrons shared?

26 Why do molecules like HCl form ions in water solution?

27 Explain the electrolysis of sedium chloride

28 What is electroplating?

29 Explain the electroplating of copper by use of the ionization theory

#### IV CHEMICAL ACTION IN SOLUTION

#### Effect of Dilution on Ionization

As has been noted, the greater the number of ions present, the better the solution will conduct the electric current. If we start with a fairly concentrated solution of a molecular compound which is capable of ionizing and begin to dilute the solution we find that the conductivity increases up to a certain point. This means that Ionization 131

in fairly concentrated solutions only a part of the molecules are dissociated into ions, but with increasing dilution more and more of the molecules ionize Of course, a point is reached where further dilution produces no more ions since there are no more molecules to ionize For solutions of ionic compounds, where there are no molecules the ions interfere with one another in the more concentrated solutions As the solutions are diluted the ions act more and more independently. In general, compounds react better in dilute than in concentrated solution as evidenced by the fact that concentrated sulfuric acid has but little effect upon zinc until the acid is diluted with water Dilution and consequent ionization overcomes the slow reaction rate The effect of dilution may also be shown by the following experiment. Place a small amount of soap powder or shavings in a tall graduated cylinder (1000 ml) Cover with about 100 ml of alcohol, add a few ml of phenolphthalem indicator, and shake for several minutes in order to dissolve some of the soap The indicator always turns red in the presence of hydroxyl ions (OH-), which are not in evidence at this stage of the experiment Add water in 100 ml amounts, shaking well after each addition Soon a faint pink color predominates, showing that with increasing dilution the molecules of the soap, which first dissolved, are beginning to produce hydroxyl ions through their hydrolysis The color deepens and deepens with increasing dilution until a red color is produced

Again to illustrate the effect of dilution on ionization, we find that glacial acetic acid does not conduct the electric current, but if the acid is diluted with water the current will flow through, showing that dilution broduces ionization and therefore conductivity

#### Strong vs. Weak Acids

In the following chapter it will be shown that all acids produce hydrogen ions in solution, a fact which accounts for the sour taste and other characteristic properties of acids. From this fact, by application of the ionization theory, it is evident that the greater the number of H<sup>+</sup> ions in solution the more pronounced are the acid properties. The common acids, HCl, HNO3, and H<sub>2</sub>SO<sub>4</sub>, ionize more than other acids and are, therefore, called strong acids. In other words, strength means the degree of ionization whether applied to acids or bases. Acids, like carbonic (H<sub>2</sub>CO<sub>2</sub>), acetic (H C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>), and boric, (H<sub>3</sub>BO<sub>2</sub>), are weak in comparison to the above mentioned common acids, because they do not ionize to any great extent to

release hydrogen ions In fact, we use dilute acetic acid (4 per cent) as a vinegar in our foods, citric acid in lemonade, carbonic acid as sad water, and boric acid as an eyewash. There are many compounds like acetic acid, the water solutions of which do not contain many ions. The molecules of such compounds are mostly cocalent, that is, they contain shared electrons between the atoms, only an occasional electron being gained or lost where there is an inequality of sharing. Thus, in the partially structural formula of acetic acid,

all bonds, except the one indicated by the vertical arrow, are strictly covalent. The bond identified by the arrow, however, has some electrovalent character. This means that occasionally a molecule of acetic acid ionizes at the point indicated to give hydrogen ion and the negative acetate ion. In many cases where there is not sufficient solubility the concentration of ions will necessarily be low, and such compounds are weak and inactive chemically

### Strong vs Concentrated Acids.

Often the term "strong acid" is used when the term "concentrated acid" should be employed Strength refers to the percentage of free H¹ one and not to the concentration of the acid molecules, which are generally unactive. The most concentrated acid has the least amount of water present, and, therefore, cannot have many H¹ one present. Concentrated sulfure acid usually contains 95 per cent of H₂SO₁, while concentrated hydrochloric acid contains about 37 per cent of Hold. The sulfure acid, then, is the more concentrated, while the hydrochloric acid is the stronger of the two in that it has a higher concentration of free hydrogen ions. Just as there are strong and weak acids, so there are strong and weak hases, the strengths of bases being determined by the concentration of OHTons. A comparison of the degree of ionization of acids of the same molecular concentration (1/10 normal\*) is shown in the following table.

<sup>\*</sup> Normal acid solution contains one gram equivalent of hydrogen per liter

### Under the same conditions, 100 molecules of

Hydrochloric acid (H+, Cl-)	wıll	yield	92.	н	ions.
Nitric acid (H+, NO <sub>2</sub> -)	**	**	92.	**	**
Sulfuric acid (H+, HSO4-)	. "	44	61.	**	**
Sulfurous acid (H+, HSO <sub>3</sub> -)	**	"	40.	**	44
Acetic acid (H+, C2H3O2-)	**	"	13	**	**
Carbonic acid (H+, HCO3-) .	**	"	0.17	**	**
Hydrosulfuric acid (H+, HS-)	**	**	0 07	**	**
Borne acid (H+, H2BO3-)	. "	**	0 01	**	"

Since practically all salts are ionic compounds, we do not speak of salts as strong or weak. Most soluble salts show a high concentration of free ions, the percentage in a N/10 (1/10 normal) solution ranging from 65 per cent to 85 per cent.

Types of Salts	Per cent of Dissociation (free ions) in N/10 Solution
M+1A-1 (eg, NaCl)	85 to 86
M <sup>+2</sup> A <sup>-1</sup> (e.g., BaCl <sub>2</sub> ) M <sub>2</sub> <sup>+1</sup> A <sup>-2</sup> (e.g., Na <sub>2</sub> SO <sub>4</sub> )	72 to 77 70 to 73
M+2A-2 (e.g., MgSO4)	50 to less

## lonization in the Fluids of the Body:

The ionization of solutions of acids, bases, and salts in the alimentary tract is illustrated by poisoning from bichloride of mercury. The water passes by osmosis from the tissues, dilutes the bichloride, causes more ions to be formed, and thereby hastens the chemical action in the tissues. Since ionization increases with dilution, a small dose of a poison is dissolved, ionized, and more quickly absorbed than an overdose. All metallic ions are quickly absorbed but slowly excreted, as most of them form insoluble compounds with the protoplasm. Lead acetate forms an insoluble protoplasmic compound, and for this reason it is used as an astringent. Salts of sodium, potassium, calcium, and magnesium are normal constituents of the fluids in the body and are therefore much used in medicines. They are seldom toxic and excretion is more rapid than absorption.

### A Newer Concept of Acids and Bases:

In the theory of ionization just presented, acids and bases in water furnish H+ and OH- ions respectively, but Bronsted (1923)

and his co workers found that acids and bases are active in non aqueous solvents in which they could not ionize. These discoveries have led to new definitions for acids and bases.

According to the Bronsted theory a proton (H<sup>+</sup>) never exists free in water or in other media, but combines with the solvent molecules. Thus with water the proton of an acid forms H<sub>3</sub>O<sup>+</sup>, called the hydronium ion, a hydrated hydrogen ion (usually represented as H<sup>+</sup>).

An acid is defined as a proton donor, strength being determined by the extent of proton transfer

Conversely, a base is a proton acceptor This means that many molecules, as H<sub>2</sub>O and NH<sub>3</sub>, and ions, such as OH-, O-, S-, CN-, HCO<sub>3</sub>-, CO<sub>3</sub>-, SO<sub>3</sub>-, are bases

Na'HCO<sub>3</sub>- + H<sub>3</sub>O+, CI- 
$$\rightarrow$$
 NaCI + 2 H<sub>2</sub>O + CO<sub>2</sub>

8010 Acid

With this somewhat recent view of a proton  $(H^+)$  the theory of ionization now is modified as follows

1 Active acids (HCl, H<sub>2</sub>SO<sub>4</sub>) in water change almost instantly into ions, whereas moderatively active acids (H<sub>2</sub>SO<sub>3</sub>, H<sub>2</sub>PO<sub>4</sub>), or sightly active acids (H<sub>2</sub>CO<sub>3</sub>, HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>) are less completely ionized because their action with water is reversible. For example

2 Active bases (the alkalies) and most salts are completely ionized even in the crystalline state since they consist of ions arranged alternately within the crystals. Consequently in aqueous solution or the melted state the crystals are broken down into freely moving ions. Thus in the process of dissolving, the ions of active bases provide hydroxyl ions (OH) which are hydrated just as are the hydrogen ions (H\*).

When metallic hydroxides as NaOH, are placed in acids, the proton transfers from acid molecules (or  $H_3O^+$  ions of dilute acids) to hydroxyl ions of the metallic hydroxide to form water, eg,

Neutralization then could be represented as follows

$$H_3O^+ + OH \rightleftharpoons 2 H_2O$$
  
 $H_3O^+ + S^- \rightleftharpoons HS^- + H_2O$   
 $H_3O^+ + CO_3^- \rightleftharpoons HCO_3^- + H_2O$ 

The main reason for denying the existence of H<sup>+</sup> ions is that the electron theory indicates the hydrogen atom is composed of one proton and one electron, and in an ionization reaction it must lose an electron in order to have a positive charge. Therefore H<sup>+</sup> ions must be protons moving independently in water solutions of acids. This is hard to believe. It seems more logical that the protons become attracted to water molecules, and experimental evidence now supports this newer concept.

Since Bronsted's concept of acids and bases has not been used consistently in general chemical literature it seems sufficient merely to introduce the theory at this time. Even though the activity of all acids is due to hydronium ions (H<sub>2</sub>O+), for convenience we more often use H+ as a general symbol to measure any acid, and OH to represent any alkali.

#### SELE-TESTING QUESTIONS

- 30 What is the effect of dilution upon ionization?
- 31 What is meant by a strong acid?
- 32 What is meant by a strong base?
- 33 Why are some acids or bases weak?
- 34 How does strength differ from concentration?

### V. IONIC REACTIONS

### Tests for lons

Sometimes a student is required to make a test for substances in solution. Usually an insoluble solid is formed as a precipitate Quite frequently a recognizable gas is liberated, and often a definite color is produced. To illustrate precipitation, suppose we wish to make a test for the chloride ion. The substance generally used for this test is a solution of silver mitrate, since it reacts with a soluble chloride to form white insoluble silver chloride.

$$Ag^{\dagger}NO_3^- \rightleftharpoons Ag^{\dagger} + NO_3^ Na^{\dagger}Cl^- \rightleftharpoons Cl^- + Na^{\dagger}$$
 $Ag^{\dagger}NO_3^- + Na^{\dagger}Cl^- \rightarrow AgCl \downarrow + Na^{\dagger}NO_3^ Ag^{\dagger}NO_3^- + Na^{\dagger}Cl^- \rightarrow AgCl \downarrow + Na^{\dagger}NO_3^-$ 

or simply,

### Preparation of an Insoluble Substance:

In the iomic reaction just discussed the silver chloride, being an insoluble solid, separates out of solution. We might have predicted that the silver ion and the chloride ion would have formed an insoluble substance if we had consulted the solubility table. If we turn to this table, page 778, and glance down the left vertical column we find Ag. Horizontally, to the right of Ag, we soon notice an I Upon raising our eyes to the top of the vertical column con an in the soluble silver in the soluble silver in the same solution would form an insoluble substance. A soluble silver salt then is used in testing for the chloride ion but not for the chlorine atom. For example, potassium chlorate contains the chlorine atom, but will not react with the silver ion to form silver chlorine.

$$Ag^+NO_3^- \rightleftharpoons Ag^+ + NO_3^ K^+ClO_3^- \rightleftharpoons ClO_3^- + K^+$$
 $Ag^+NO_3^- + K^+ClO_3^- \rightleftharpoons Ag^+ClO_3^- + K^+NO_3^-$ 

It will be further noticed in the solubility table that this compound, AgClO<sub>3</sub>, is soluble as evidenced by the W which means water soluble. It is quite evident then that the solubility table serves as a means of indicating what combinations of ions will form soluble or insoluble substances. As a further aid in testing, it quite frequently happens that the insoluble substances fromed are colored

In a previous paragraph, it was stated that all acids have com mon properties, since they provide the common hydrogen ion. The color of many salt solutions is due to one of their common ions. For example, the green solid CuCls, or the dark brown solid CuBr in dilute solutions is blue, because of the common cupric ion. Cu<sup>++</sup> So it is that any solution containing the same common ion (OH<sup>-</sup>, Cl<sup>-</sup>, Sol<sup>-</sup>, etc.) generally reacts in the same way and responds to certain specific tests.

## Reactions Which Go to Completion:

In some of the equations presented in this chapter the double arrow has been used to indicate that these reactions "work backward," ie, they are reversible Both the direct and reverse reactions continue simultaneously in a state of dynamic equilibrium

For those reactions which go to completion, only one arrow is used in the equation, and pointed in the forward direction. Here one or more of the products formed must leave the field of the reaction as (1) insoluble (2) volatile or (3) un ionized. Examples of these types are given in the following equations

```
Ag^+NO_3^- + N\alpha^+Cl^- \rightarrow N\alpha^+NO_3^- + AgCl \downarrow \text{ (Insoluble)}

N\alpha^+HCO_3^- + H^+Cl \rightarrow N\alpha^+Cl + H_2O + CO_2 \uparrow \text{ (Volatile)}

N\alpha^+OH + H^+NO_3^- \rightarrow N\alpha^+NO_3^- + H_2O \text{ (Und sociated)}
```

### Value of the lonic Theory:

The theory of ionization is a practical aid in helping to explain many chemical reactions which take place in solutions of acids, bases, and salts. Thus far, the theory has given a fairly satisfactory explanation of the following facts

- 1 The abnormal effect of electrolytes as compared to nonelectrolytes on the boiling point, freezing point, and the osmotic pressure of solutions
- 2 Electrolysis and electroplating
- 3 The greater chemical activity of electrolytes as compared with nonelectrolytes
- 4 Different strengths of acids and bases
- 5 Prediction of the behavior in solution of substances yielding

In addition to the above facts, advanced chapters will consider other important ionic reactions such a neutralization, replacements of metals by other metals, chemical reactions between electrolytes, and hydrolysis of salts

#### SELF-TESTING QUESTIONS

- 35 How can you usually tell whether you are getting a test for an ion?
- 36 How can you predict whether a reaction will form a precipitate?
  37 Are precipitation tests used for ions or for atoms?
- 38 Why are dilute solutions of CuSO4, CuCl, and CuBr, all blue?
- 39 The ionization theory is used to explain the reactions which take place between what classes of compounds?

- 40 When will reactions between ions take place?
- 41 What are five uses of the ionization theory?
- 42 What types of chemical reactions go to completion?
- 43 What is the nature of the reversible reaction?

#### VI. STAINS

Note The remainder of this chapter may be omitted when time must be saved It may be given as a reading assignment in conjunction with the laboratory exercise on stains

### Stain Removal.

In the hospital, home, laundry, or dry cleaning establishments there are frequent demands made for the removal of stains, and especially so in connection with the general care of clothing. Although many of the methods employed demand special knowledge in the chemistry of textiles and stains, most stains may be removed effectively and inexpensively in the home if a few simple precautions are taken. Of all the rules to follow, the most important is prompt treatment of the stain, since upon prolonged exposure to the air. washing, ironing, or other factors, many stains undergo a chemical change to form stains that in some cases are almost impossible to remove without serious injury to the fabric Stains of a physical nature, as grease or fresh paint, are of the class easily removed by selecting the correct solvent, but if on the other hand the stain has undergone a chemical change, as old ink stains, then a chemical must be used to change it back into a form that is soluble and which may be washed out. Most chemicals applied to fabrics have a tendency to weaken and destroy the fibers

Just as in any ailment, we must first understand the nature of the trouble, so we must know the nature of the stain before proper treatment may be given Trying out different chemical compounds upon stains of unknown composition may cause the stain to become more insoluble For instance, such a simple and apparently harmless compound as hot water may be of great assistance in removing fresh ink, or most fruit stains, yet in the case of protein stains (milk, eggs, blood) hot water coagulates the afbuminous material and makes it very difficult to remove. Also a failure to know the nature of the fabric and dyestuffs in many cases will result in a loss of the dyestuffs and murry to the goods. This is especially so in attempting to remove stains from material made of both aims and vegetable fiber, such as silk and cotton. Furthermore, there are many synthetic fabrics on the market, such as rayon or cellulose acetate, which certain chemicals (acetone, chloroform, acetic

Ionization 139

acid, alkalies, bleaching agents) dissolve. Also, there are fabrics which contain certain amounts of weighted materials (tin compounds) which are very much affected by certain solvents. In view of the above statements, unless thoroughly familiar with the nature of the stain and the kind of fabric, as a rule, it will be more satisfactory to have the stains removed by a reliable dry cleaner who employs one or more "spotters" trained in this work.

### Stain Removal Methods:

The removal of stains, called "spotting jobs," consists of four types solvent, absorption, digestive, and chemical

- (1) By the solvent type is meant the application of some solvent to the stain that will dissolve it from cloth. As an example of this type of solvent we refer to the removal of sugar spots by the use of water. Other solvents are acetone, ether, alcohol (wood or grain), carbon tetrachloride, trichloroethylene, and certain hydrocarbons such as nanhtha, gasoline, and turnentine.
- (2) The use of whiting on white shoes is a very good example of removing stains and dirt by absorption Other absorbents are



Fig. 6—Stain Removal Treating a stain with sadium perborate bleach. What other bleach solutions might be similarly used Courlesy, U.S. Department of Agriculture.

magnesium carbonate, fuller's earth, corn meal, and certain chalks (CaCO<sub>3</sub>, MgO) In conjunction with this method, many stains insoluble in the fabric such as some lipsticks, mascara, and inks may be lubricated by applying an oil which carries or slides the insoluble pigment from the goods

(3) In the case of coagulated albuminous stains, it is often necessary to use enzymes or digestive agents which decompose

protein into water soluble substances

(4) When the above methods are ineffective, certain chemical reagents must be used to change the insoluble stain into a soluble or colorless stain Such chemicals usually are bleaches chlorine, chlorine compounds, hydrogen peroxide, potassium permanganate, oxalic acid, sodium perborate, and hydrosulphites

From the foregoing it is evident that the spotter must know his textile, his dyes, and the effect of chemicals upon them

## Wet and Dry Cleaning:

In a few cases, more so in the South where there are more linen, flamiel, and summer suits worn, there is some demand for wet cleaning. Steam is seldom used since it may result in shrinkage and injury to many fabrics.

By "dry cleaning" we mean the use of volatile organic solvents to the exclusion of water. In the modern dry cleaning plants, the material is agitated in a closed drum with some volatile organic solvent as naphtha, benzine, trichloroethylene, or carbon tetra chloride (Carbona), the latter two solvents being the safest since they are nonflammable Under the name of Stoddard Solvent, and various trade names, dry cleaning plants and homes are using an inexpensive petroleum distillate, which not only is free of objection able odors, but also is almost nonflammable. It is a reasonably safe solvent since its boiling point is above that of gasoline and be low that of kerosene, and unless the temperature is very high there is not sufficient vapor to support a flame or cause an explosion When properly done, dry cleaning generally restores silk, wool, and synthetic fabrics to their original condition without the dangers of loss of shape, texture, or drape. As a rule, not only is all of the soil and grease removed, but also germs and insect life are killed If for no other reason than the latter, dry cleaning should be a general rather than an occasional practice. Very few people realize and appreciate the importance of dry cleaning from the standpoint of health

When a solvent such as naphtha, trichloroethylene, or Carbona is used on a piece of cloth to remove a stain such as grease, the grease is dissolved by the reagent and is spread as far as the liquid penetrates the goods. The solvent upon evaporation leaves such a tim layer of grease that it is not perceptible on rough woolen goods. Of course, some may be removed by penetrating the cloth used in rubbing the grease spot. On the other hand, when used on thin silk goods, the tendency is simply to enlarge the spot and leave a ring of grease after evaporation of the solvent. From this it is evident that to thoroughly remove the grease, the goods must be rinsed repeatedly in fresh solvent. This is the method used in dry cleaning establishments.

## Ousting the Clothes Moth.

In the early days the common procedure against clothes moths was to use moth balls, formerly of camphor, now of naphthalene 'The best either substance did was to prevent moths from laying eggs on stored material

Paradichlorobenzene, commonly called dichloricide, ushered in a new era of clothes moth control since for the first time there was available a handy crystalline material that not only would keep clothes moths away but also would slowly kill the eggs and larvae A half pound or more of the crystals placed on the highest shelf in clothes closets will protect clean fabrics. Furs though are kept more safely in cold storage where at a temperature below 40°F the young larvae are inactive and cannot survive many weeks.

If moths have become entrenched then they must be killed by some spray material such as DDT or chlordane

Clothes frequently used, exposed to bright light or dry heat do not harbor moths Garments should not be stored at home without first being dry cleaned, because soiled clothing attracts moths much more readily than clean clothing

#### SFLF-TESTING QUESTIONS

- 44 Why should a fresh stain receive prompt treatment for removal?
- 45 Why should the nature of the stain be known before treatment?
- 46 State and explain the four general methods of removing stains
- 47 How are clothes dry cleaned?
- 48 Why is it important to have suits dresses etc dry cleaned even though such garments are not soiled from wearing?

### SUGGESTED ACTIVITIES

- I THOUGHT PROVOKING QUESTIONS
  - 1 Why is salt thrown on icy sidewalks or on the ice in an ice cream freezer?
  - 2 In sea bathing why do you not feel any electric shocks from the ions of salts?
  - 3 What is the effect of substances dissolved in water with regard to the properties of the solution?
  - 4 In what way can you account for the difference in the properties of electrolytes as compared to nonelectrolytes?
  - 5 What facts led to the formation of the ionization theory?
  - 6 Why are ions of chlorine not as active as the atoms or molecules of chlorine?
  - 7 What is the effect of passing a current through a solution con taining an electrolyte?
  - 8 Explain your distinction between a molecule, an atom, and an ion of chlorine
  - 9 If the charge on an ion is altered might the color be changed?
    Illustrate by an example
  - 10 Vinegar or lemon juice is used in making salads. Why could not an equivalent amount of hydrochloric acid be used?
  - 11 Salt is cheaper and more effective than alcohol for antifreeze mixtures. Why not use it in the radiator?

    12 What important difference between calcium chloride and carbon.
  - 12 What important difference between calcium chloride and carbo tetrachloride is not shown by the formulas CaCl<sub>2</sub> and CCl<sub>4</sub>? 13 The sodium ion and the belium atom are alike in what respect?
  - 14 The statement was made that crystals contain ions Why, then, must most crystals of salts be melted before much current will go through them?
  - 15 Write an ionic equation showing the reaction of hydrochloric acid upon sodium carbonate to produce water and the volatile gas carbon dioxide
  - 16 Write an ionic equation between sodium phosphate and calcium chloride to show the formation of insoluble calcium phosphate

### II VOCABULARY TESTING OF NEW TERMS

nonnolar compound anode gram molecular weight electroplating cathode strength of acids and electrode valence electron electrolysis nolar compound hagen electrolyte electrovalence covalence nonefectrofyte reversible reaction covalent electrocardiograph phered electron mole

- III TOPICS FOR ORAL OR WRITTEN REPORTS
  - 1 Some Processes Dependent upon Ions 2 Stains, and How to Remove Them
  - 3 The Electrolytic Production of Sodium Hydroxide from Salt

#### LABORATORY CHEMISTRY

#### CHAPTER VII

## ACIDS

#### CHAPTER OUTLINE

1	GENERAL FACTS ACIDS	CONCERNING	111	Some Organic . (a) Acetic acid

(a) Classification (b) Properties of acids

(c) Individual differences

(d) Antidotes for acids (e) Naming of inorganic acids

II Some Inorganic Acids

(a) Hydrochlone acid (b) Hypochlorous acid (c) Nitric acid

(d) Sulfuric acid

(e) Sulfurous acid (f) Borne acid

(a) Acetic acid

(b) Benzoic acid (c) Tartaric acid

(d) Citric acid (e) Lactic acid (f) Oxalic acid

(g) Salicylic acid (h) Formic send (1) Amino acida

(1) Palmitic acid steams and olele IV COMPARISON OF INDRGANG AND

Actns

ORGANIC ACTOS

### I. GENERAL FACTS CONCERNING ACIDS

There are thousands of morganic compounds, the majority of which belong to one of three classes, known as acids, bases, and salts Acids are especially important to the nurse because of their functions in the human body and the place that they hold in the composition of our foods Fruits and fruit juices contain organic acids Acids are constantly being formed in the body-gastric juice and urine are distinctly acid solutions

### Classification

Acids are classified as inorganic and organic Organic acids are usually derived from organic matter, i e, plant or animal matter, while the morganic commercial acids are derived from manimate sources Some of the important acids of each class are listed as follows

Inorganic		Orgo	ansc
Hydrochloric acid	HCl	Acetic acid	H CaHaOa
Nitric acid	HNO <sub>3</sub>	Benzoic acid	H C7H6O2
Sulfuric acid	H <sub>2</sub> SO <sub>4</sub>	Carbonic acid	H <sub>2</sub> CO <sub>2</sub>
Hypochlorous acid	HCIO	Citric acid	Ha CoHaOr
Sulfurous acid	H <sub>2</sub> SO <sub>3</sub>	Formic acid	H CHO <sub>2</sub>
Boric acid	H <sub>3</sub> BO <sub>3</sub>	Lactic acid	H CaHaOa
Phosphoric	H <sub>3</sub> PO <sub>4</sub>	Malic acid	H2 C4H4O4
Nitrous	HNO <sub>2</sub>	Oxalic acid	H <sub>2</sub> C <sub>2</sub> O <sub>4</sub>
Hydrosulfuric	$H_2S$	Salicylic acid	H C7H5O2
Phosphorous	H <sub>3</sub> PO <sub>3</sub>	Tartane acid	H2 C4H4O4

### Properties of Acids, i.e. H+ ions

Ordinarily, we think of an acid as a liquid, but usually these liquids are solutions of gases, liquids, or solids in water. For example hydrochloric acid is a solution of a gas, hydrogen chloride, sulfuric acid is a solution of a liquid, hydrogen sulfate, while boric acid is a solution of a solid.

The formulas show that all acids contain the common element hydrogen, combined with atoms of a nonmetal, or groups of nonmetallic atoms called acid radicals. In hydrochloric acid (HCl). for example, the nonmetallic element is chlorine (Cl), while in sulfuric acid, the acid radical is the sulfate radical (SO4) The nonmetals, then, are to be considered as acid forming elements. Since every acid is a hydrogen compound which in aqueous solution produces the H+ ion, it is reasonable to think of the common and characteristic properties of all acids as being due to the H+ ion As has been stated some acids are stronger than others, strength being determined by the concentration of H+ ions. Use of the terms concentration and strength should not be confused. A concentrated acetic acid solution contains a high percentage of undissociated acid molecules, thus a concentrated solution of acetic acid is not nearly as strong as a solution of hydrochloric acid, since strength depends upon degree of ionization

The characteristic properties of acids follow

1 ACIDS ARE ELECTROLYTES All acid solutions will conduct an electric current, that is, the solutions are electrolytes Examples of the contration of acids in solution follow

- 2 Acms Have a Sour Taste When acids dissolve in water they impart a sour taste to the water Sour tasting solutions generally contain acids For example, the sour taste in lemons, grapefunt, oranges, and dunness is due to citric acid
- 3 ACIDS ACT ON SOME COLORED COMPOUNDS Many compounds known as indicators change color in the presence of acids. The most common substance so used is blue litmus dye, which changes to a red color in the presence of acid solutions. This is the simplest recognition test for an acid.

4. ACIDS ACT ON MOST METALS. When certain active metals, as iron, magnesium, or zinc, are put into acid solutions the metals react and hydrogen gas is usually liberated. From the electron standpoint, metals have atoms that lose one or more electrons to hydrogen ions, which then become ordinary hydrogen atoms.

$$Na^{\circ} + H^{+}CI^{-} \rightarrow Na^{+}CI^{-} + H^{\circ}$$

Then two hydrogen atoms, each sharing its electron with the other, combine to form a molecule of hydrogen gas (H<sub>2</sub>) which escapes The formation of hydrogen may easily be shown by placing a piece of zinc in a test tube which contains a few ml, of dilute sulturic acid. The presence of the hydrogen is shown by holding a lighted match over the mouth of the test tube. A small explosion usually occurs, when there is some oxygen mixed with the hydrogen. This is a common laboratory test for molecular hydrogen. Pure hydrogen issuing from a jet burns quietly, with a blue flame.

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$$

#### DISPLACEMENT SERIES

(Partial list)

Displace hydrogen from water Vigorous reaction with acids	K Na (Ca
Displace hydrogen from steam and from acids	Al Zn Cr Fe
Displace hydrogen slowly from acids	Nı Sn Pb
Do not displace free hydrogen from acids May react with acids	Cu Sb Hg Ag Pt

Fig 1.

However, not all metals have the ability to displace hydrogen from acids. In Figure 1 metals are arranged in a series showing the order of their activity in this respect. The most active elements are placed at the top, and they readily displace hydrogen from water Any metal on the scale above hydrogen will replace hydrogen from an acid, with the exception of concentrated intra card which oxidizes the hydrogen to water. The metals below hydrogen on the scale will not displace hydrogen from the acids.

This property of certain metals to displace hydrogen in acids explains why metal utensils are not used in preparing acid foods It is interesting to note that each metal on the scale will displace any one below it from its salts in solution. For example

5 Acids Act on Metallic Oxides and Hydroxides When water solutions of acids are brought in contact with the oxides or hydroxides of the metals (p. 159), salts and water are formed

ZnO 
$$+$$
 H<sub>2</sub>5O<sub>4</sub>  $\rightarrow$  H<sub>2</sub>O  $+$  ZnSO<sub>4</sub>
Metall c oxide Saty
NaOH  $+$  HCl  $\rightarrow$  H<sub>2</sub>O  $+$  NaCl
Metall c bydroxide Salt

These equations represent neutralization (explanation, p 173), a useful reaction in counteracting the action of an acid or a base

6 ACIDS ACT ON CARBONATES Whenever an acid solution is brought in contact with a carbonate, there is formed a salt and a weak unstable acid, carbonic acid, which quickly decomposes (effervesces) into carbon dioxide and water \*

This is the type of reaction which takes place in a commonly used fire extinguisher as was explained in Chapter III It is also the reaction which takes place when sodium hydrogen carbon ate (baking soda) is used to overcome high acidity of the stomach Normally the acid in the stomach is either hydrochloric acid or the acids formed by fermentation of foods. The equation shows the action between baking soda and hydrochloric acid.

$$\begin{array}{ccc} \text{NaHCO}_3 + \text{HCI} \rightarrow \text{NaCI} + \text{H}_2\text{CO}_3 \\ & \downarrow \\ \text{Boking} & \downarrow \\ \text{soda} & \text{H}_2\text{O} + \text{CO}_2 \end{array}$$

<sup>\*</sup> Generally speaking salts of any volatile acid react with a nonvolatile acid

The use of baking soda with sour milk (lactic acid) in baking is another example of an acid reacting with a carbonate. It is a similar reaction that takes place when baking soda and orange juice (citric acid) are used with castor oil for laxative purposes. The carbonic acid makes the oil easier to take. Again, the interaction of an acid and a carbonate is the typical reaction of baking powders, since all such powders contain a carbonate and some acid forming substance.

7. ACIDS ACT ON THE TISSUES. The physiological action of strong, concentrated acids (as sulfuric, nitric, and hydrochloric) upon the tissues is to destroy the tissues by their corrosive (coagulation and dissolving) action. However, when these acids are in a very dilute form they only abstract water from the tissues. In fevers certain acids may be used to diminish thirst, because they stimulate the flow of saliva It is for this reason that lemonade (citric acid) finds a use in relieving thirst.

Since animal fibers such as silk and wool, like body tissues, are of protein composition, fabrics made of these fibers are also affected by strong concentrated acids. The action is less marked on vegetable fibers (cellulose) such as cotton.

These seven general properties of acids are to be remembered



Fig 2—Three Important Muneral Acids These three common liquid acids are widely used in the laboratory and are indispensable for commercial use Con you name some other acids used in the hospital<sup>2</sup>

since they can be applied to almost every soluble acid. The study of each acid, then, will only involve learning the special or "trick" performance of that acid.

#### Individual Differences of Acids

Even though acids form a group and exhibit many general properties in common, still they, like people, may possess properties peculiar to themselves Thus, some acids are very stable (sulfuric), other ones are unstable (carbonic), some are colored (picric), other ones are colorless (tartaric), some are very poisonous (oxalic), other ones are harmless (carbonic) and some may even be used medicinally (citric). A few are not even sour tasting (insoluble stearch), and of course, there is considerable variation in their chemical behavior

As has been mentioned all acids in water produce the hydrogen ion, H<sup>+</sup>, and so acids may be defined as compounds producing hydrogen ions, and no other positive ions, in aqueous solution. How ever, it must be remembered that not all hydrogen compounds are acids. For example sugar (C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>) although containing hydrogen does not produce the H<sup>+</sup> ion and therefore is not an acid.

### Antidotes for Acids

From a study of the properties of acids it is evident that any carbonate, such as baking soda and chalk, or any mild hydroxide as linewater and milk of magnesia, or even soap suds may be used as effective antidotes for mineral acid poisoning. In the case of some organic acids special reagents are preferred to the above-mentioned compounds.

To counteract the action of an acid spilled upon the clothing or skin, the first step is to remove as much of it as possible by running water. The remaining acid is then neutralized, preferably by dilute ammonium hydroxide, since any excess of this reagent soon evap orates without mjury to the clothing or skin. Acids spilled on the floor may be neutralized by continued additions of baking soda until effervescence ceases.

## Naming of Inorganic Acids

Some acids contain only one other element in addition to hydrogen. These acids are called binary acids. Binary acids are given names consisting of the prefix hydro, to represent the hydrogen, the root of the second element, plus the suffix ic. For example HCl is named hydro-chlor-ic acid. Oxygen is the third element in a great majority of the acids Such acids which contain three elements are called ternary acids, and receive their name from the element other than the hydrogen and oxygen. For example, HNO<sub>3</sub> is nitric acid, and H<sub>2</sub>PO<sub>4</sub> is phosphoric acid. If three elements unter in different proportions to make several different acids, the best known is given the suffix ic, as H<sub>5</sub>SO<sub>4</sub>, which is called sulfuric acid. An acid with less oxygen than the most common one has the ending ous, as H<sub>5</sub>SO<sub>3</sub> which is named sulfurous acid. It sometimes happens that there are more than two ternary acids composed of the same three elements. In such a case use is made of the prefix per, meaning "more," and hypo, meaning "less," atoms of oxygen in the molecule. The following ternary acids of chlorine and phosphorus illustrate very well the method of naming them:

	Ternat	y Acids	
HClO <sub>4</sub> HClO <sub>3</sub> HClO <sub>2</sub> HClO	per-chlor ic chlor ic chlor-ous hypo-chlor-ous	H <sub>3</sub> PO <sub>3</sub> H <sub>3</sub> PO <sub>2</sub>	phosphor to phosphor-ous hypo-phosphor-ous

In organic chemistry there are so many acids composed of only hydrogen, carbon, and oxygen that it is impossible to use this system for naming organic acids. For this reason many organic acids are named either because of their source (citric acid, from citrus fruits), or some individual characteristic. Also, there are scientific nomenclatures for organic acids

#### SELF-TESTING QUESTIONS

- 1 Into what two groups are acids classified?
- 2. What two fluids of the body are normally acid?
- 3. The properties of a soluble scid involve the study of what ion?
- 4. What class of elements is acid forming?
- 5 Soluble acids are characterized by what general properties?
- 6 Define an acid.
- 7. Antidotes for acids depend upon what properties of acids?
- 8 What are binary acids and ternary acids, and how are they named?

### II. SOME INORGANIC ACIDS

Of the many acids, the following are of special interest to nurses: Hydrochloric Acid (HCI):

This acid plays a very important part in the chemistry of the body. Hydrochloric acid is found in the gastric juice where the

acid is present to the extent of about 0.2 to 0.5 per cent. Gastric digestion does not take place except in the presence of this acid, which is produced in the body from salt and water that is taken with the food. In addition to aiding digestion, hydrochloric acid destroys fermenting bacteria which might cause disturbances in the intestinal tract. Sometimes it is necessary to make a gastric analysis in order to find out how much and is present. If the per centage of  $H^+$  ions is above normal (stomach inflammation or gastritis) the condition is known as hyperacidity, but if below normal (gastric juice of many old people) it is called hypocacity. In hyperacidity it is frequently necessary to give some harmless basic acting substance as magnesium oxide, while in hypoacidity very dilute hydrochloric acid supplies this deficiency.

### Hypochlorous Acid (HCIO)

This is a powerful bleaching agent. Its bleaching properties are due to the ease with which it frees its oxygen, and it is the free oxygen which oxidizes the colored materials into colorless comnounds.

The oxygen set free in such a manner is called nascent oxygen and is much more active than ordinary oxygen gas. Many diseases are caused and communicated by munte microgramsms called bacteria which are readily killed by this acid. In addition to its remarkable antiseptic powers hypochlorous acid dissolves and removes dead tissue.

Calcium hypochlorite, often incorrectly called "chloride of lime," a substance which generates this acid has long been used as a bleach and disinfectant for saintary purposes in the home and hospital Within recent years a sodium compound of this acid called sodium hypochlorite has been used in very dilute solution as an antiseptic agent in surgery. The best known solution for this purpose is Dakin's solution which is used in washing wounds Dakin's solution is a neutral sodium hypochlorite solution, con taining 0.45 to 0.50 per cent NaClO. It possesses high toxicity for bacteria and low toxicity for tissue cells. It should be used within 24 hours as upon standing there are formed higher oxides of chlorine and free chlorine which irritate the wound. When the solution is used the patient is so postured that a stream of the solution continually passes into and out of the wound. The sodium hypo

chlorite, like hypochlorous acid, decomposes to liberate oxygen for oxidizing purposes.

#### NaCIO → NaCI + (O)

Dakin's solution is made by passing chlorine gas into a weak sodium carbonate solution. Care must be taken so that the solition will not be too alkaline because it then has an irritating effect, and the added undesirable action of more readily dissolving blood clots. Commercial preparations containing sodium hypochlorite, Clorox for example, are used for bleaching purposes.

One part of hypochlorous acid in a million parts of water will destroy all the bacteria in water. This method has been adopted by many cities for purifying drinking water. The method usually followed is to pass a stream of chlorine gas from steel cylinders into the water supply. The chlorine with the water forms the hypochlorous acid, which in the presence of the bacterial and organic matter liberates nascent oxygen, thus oxidizing and destroying the bacteria.

### Nitric Acid (HNO<sub>3</sub>):

Commercially this acid is used for the preparation of such organic compounds as explosives and dyes. When nitric acid is brought in contact with the skin or a piece of wool a yellow stain is produced. Nitric acid is used as a coagulant in testing for albumin in the urine (p. 392).

### Sulfuric Acid (H2SO4):

This is the most important commercial acid, and it is used in enormous quantities. In dilute solutions sulfuric acid is used in storage batteries, and in cleaning the surfaces of many metals.



Fig.—3 A Dehydrating Agent. Sulfuric acid not only will absorb free water, but also will withdraw the elements of water from certain organic compounds such as sugar (C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>). Why can it not be used to dry all acuses?

Iron so treated and coated with zinc is called galvanized iron Enormous quantities of the acid are used in refining petroleum in making fertilizers, and in the preparation of dyestuffs and explosives. Concentrated sulfuric acid has a great affinity for water and for this reason it may be used as a dehydrating agent. In this respect, sulfuric acid is so powerful that it will abstract the elements of water from many organic compounds which contain hydrogen and oxygen, leaving carbon as a black residue (Fig. 3). This acid is rarely used in medicine.

### Sulfurous Acid (H2SQ3):

This is the result of burning sulfur to form sulfur dioxide and passing the gas into water

Sulfurous acid readily combines with oxygen, taking it from the air or from some unstable substance containing oxygen

On account of this property sulfurous acid is a powerful reducing agent. Because of its reducing action, sulfurous acid has strong bleaching properties and is used to bleach paper, straw goods, silk, wool, and even such foods as dried fruits, canned corn, and cherries. The bleaching effect is not permanent and disappears after a time, hence materials, like straw hats and paper, become "yellow with age".

### Boric Acid (H3BO3):

This is also called borace acid. It is but spannigly soluble in water and ionizes so slightly in water that it scarcely reddens litmus or exhibits any acid properties. It is a mild antiseptic for inflamed mucous membranes of the eyes, nose, or mouth, being especially valuable in a saturated aqueous solution as an eye and mouth wash

### SELF-TESTING QUESTIONS

- 9 Where is hydrochloric and found in the body? In what concentration?
   10 How does chlorine react with water?
   11 What is Dakin is solution and how do you account for its antiseptic
- 11 What is Dakin's solution and how do you account for its antiseptic properties?
- 12 What is the most important commercial acid?
- 13 Why does fumigating with burning sulfur tend to bleach materials?
- 14 What saturated acid solution is commonly used for inflamed muccous membranes?

#### III. SOME ORGANIC ACIDS

### Acetic Acid (C2H4O2, generally written as H · C2H3O2):

This acid may be derived from alcohol through fermentation brought about by a minute organism present in the so called mother of unegar, or it may be obtained by the destructive distillation of wood Vinegar may also be made from beer (malt vinegar), from wine (white wine vinegar), or from molasses. Since bacteria are present in the air and on the skins of fruits, acetic acid is produced whenever a dilute solution of alcohol, with some food for the micro organisms, is left exposed to the air. If the percentage of alcohol runs too high (10 per cent), the bacteria are not capable of forming the acid. Acetic acid, as in vinegar, is used as a condiment Glacial acetic acid (99 5 per cent) forms ice like crystals when cooled below 16° centigrade.

## Benzoic Acid (H · C7H5O2)

A salt of this acid, sodium benzoate, is used as an antiseptic in the intestinal and urinary tracts, and also as a preservative Saccharin, a substance approximately 400 to 500 times sweeter than sugar, is a denvative of benzoic acid Saccharin has no food value as it is not oxidized by the body

## Tartaric Acid (H2 · C4H4O6)

This acid is found in grapes and many other fruits, however, it usually occurs as potassium acid tartrate (KHC4H40a), a substance which is commonly known as cream of tartar and is useful in making baking powder and effervescent powders as "Seidlitz powders." Tartaric acid is also used in some soft drinks, such as ginger ale This acid may be used medicinally to increase the flow of urine (diuretic), or as a mild laxative

### Citric Acid (H3 · C6H5O7)

This acid occurs in many fruits, as oranges, lemons, and berries of all sorts. Citrate of magnesium is used in medicine as a purgative. The junces of fruits containing citric acid, especially oranges and lemons, are used as dietary preventives against scurvy, to replace lost alkali in the blood (explanation p. 185), and in the form of hot lemonade to act as a diuretic.

### Lactic Acid (H · CaHsOa):

Milk sours when the sugar present is acted upon by certain microorganisms in the air, producing lactic acid. As mentioned in Chapters I and III, exercise of the muscles produces lactic acid, which is immediately oxidized. However, if undue exercise causes an excessive amount of lactic acid to collect, the oxidation is not completed and fatigue results. Any increase in acidity of the body cells slows down their activity because of the fact that oxidation becomes slower. Then the issues, being of a colloidal nature, adsorb water and swell. Butternilk and sauerkraut, which contain lactic acid, will prevent the growth of putrefactive bacteria in the large intestines and so change the intestinal flora. Lactic acid milk finds some use in infant feeding since it produces an easily digested curd, and also is of aid in overcoming diarrhea.

### Oxalic Acid (Ho . C.O.):

This acid occurs in many plants in the form of salts. It is used to remove mk and iron rust from cloth, to clean such metals as copper, and to bleach or clean straw hats. Oxalic acid is very poisonous

### Salicyle Acid (H · C-H-O-):

In the form of a salt, salicylic acid is used as a food preservative and in medicine as an antiseptic. Oil of wintergreen for treatment of acute articular rheumatism and aspirin for relieving colds and neuraligic pains are products made from this acid.

## Formic Acid (H · CHO<sub>2</sub>)

Formic acid occurs in nettles and it is secreted by ants. The irritation caused by the sting of an ant or bee is due to the presence of this acid, making understandable why soda is applied to such irritations.

### Amino Acids:

They are formed both in plants and animals. In animal bodies they are the result of the *digestion* of proteins, and are discussed in the chapter on proteins

## Palmitic Acid, Stearic Acid, Oleic Acid.

These three acids are very important since they enter into the composition of many of the fats and oils which occur in our foods Further discussion will be given in the chapter on fats

#### SELF-TESTING QUESTIONS

- 15. What acid occurs in vinegar, and for what is it used?
- 16. What two acids form salts that are used as food preservatives?
- 17. Where does tartaric acid occur and for what is it used?
- 18. Citric acid in the form of lemon or orange juice has what use?
- 19. What organic acid has bleaching properties?
- 20. Digestion of proteins produces what acids?

### IV. COMPARISON OF INORGANIC AND ORGANIC ACIDS

The effects of certain organic acids such as acetic, tartaric and citric in the body are similar to those of inorganic acids except that they are milder and after absorption act as alkalies. The following table compares their internal action:

Inorganic Acids	Organic Acids
Increase the flow of saliva Aid digestion in the stomach, since	Increase the flow of saliva Aid digestion in the stomach by
	stimulating the appetite and the flow of gastric juice
Increase the flow of pancreatic juice	Slightly laxative, e.g., lemon juice be- fore breakfast
Increase the acidity of the blood	Increase the flow of urine Act as an alkali in the blood

Organic acids are exidized in the body cells with the formation of carbonates and consequently are base-forming substances, as will be explained in the chapter on salts (p. 188).

#### SELF-TESTING QUESTIONS

- 21. What are the internal uses of organic acids?
- 22. How do they differ from inorganic acids in their internal action?

### SUGGESTED ACTIVITIES

- I. THOUGHT-PROVOKING QUESTIONS:
  - 1. Name the three most common strong acids used in the laboratory.
  - 2. How does a strong acid differ from a weak acid?
  - 3. Why should surgical instruments not come in contact with acids?
  - 4. Why should baking powders, or effervescing powders, be kept in a dry place?
  - Give the classification and name of the following compounds:
     H<sub>2</sub>PO<sub>2</sub>
     H<sub>2</sub>PO<sub>4</sub>

- 6 Why not use a dilute rather than a concentrated or a saturated solution of bonc acid as an eyewash?
- 7 Instead of using sour milk and baking soda for baking, what solid acid compound could be used?
- 8 Explain the formation of vinegar from sweet cider
- 9 What are organic acids and how do you account for such a great difference in the chemical action of organic acids as compared to morganic acids?
- 10 Give the formulas and names of all the possible acids containing the elements hydrogen, sulfur, and oxygen
- 11 In comparing the activity of acids in solution how much replaceable hydrogen must be in each solution?
- 12 What is the underlying general reaction involved when effer vescing salts are dissolved in water?

### II VOCABULARY TESTING NEW TERMS

ternary acid

acid 'per binary acid 'hyr

'per' nascent
'bypo' reducing agent

- III TOPICS FOR ORAL OR WRITTEN REPORTS
  - 1 Antidotes for Common Acids
  - 2 Gastric Acidity as a Diagnostic Tool
  - 3 Theories Concerning the Formation of the Hydrochloric Acid in the Stomach

hyperacidity

4 Uses of Hypochlorous Acid and Its Various Salts

#### LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on pages 674, 676

### BASES

#### CHAPTER OUTLINE

- I PROPERTIES AND ACTION OF BASES
  - (a) Properties of soluble bases
  - (b) Antidotes for bases (c) Strong vs concentrated
- II TYPICAL BASES (a) Sodium hydroxide or
  - caustic soda (b) Calcium hydroxide or
  - slaked lune

- (c) Ammonium hydroxide or aqua ammonia (d) Magnesium hydroxide or
- milk of magnesia
- III Hydrogen Ion Concentration
  - (a) Hydrogen 10n scale (b) Meaning of pH scale
  - (c) Indicators

disease

- (d) Testing for pH values (e) Hydrogen content vs hydrogen
- ion concentration (f) Applications of pH value to
- 1. PROPERTIES AND ACTION OF BASES

### Properties of Soluble Bases (OH- ions):

A study of aqueous solutions of the following typical bases shows that they all have common and characteristic properties NaOH

Sodium hydroxide Potassium hydroxide Ammonium hydroxide Calcium hydroxide Magnesium hydroxide

KOH NHAOH Ca(OH) 2 Mg(OH)a (Caustic soda) (Caustic potash) (Ammonia water) (Lime water) (Milk of magnesia)

A glance at the preceding formulas for the common bases shows that they all contain one or more groups of oxygen and hydrogen in combination This characteristic OH group is called the hydroxyl radical and it is combined with a metal or with the metal like NH4 radical to form the bases The metals are base forming elements Since every soluble base contains the hydroxyl group, which in aqueous solution furnishes the OH~ ion, it is reasonable to conclude that the characteristic properties of all soluble bases are due to the hydroxyl ion A base is a compound which furnishes hydroxyl ions (OH-) in solution.

$$Na^{+}OH^{-} \rightarrow Na^{+} + OH^{-}$$

Soluble bases, therefore, are typical electrolytes. Later, when studying organic compounds, we shall learn about some compounds such as the alcohols and sugars which have one or more hydroxyl groups, but which are not bases in the sense that they do not ionize to furnish the hydroxyl ion (p. 284). The characteristic properties of bases follow:

 Bases Have a Soapy Feeling. A strong base like sodium hydroxide (Iye) when dissolved in water feels slippery or soapy. Such bases are caustic, and can change the natural oil of the skin into soap, and "burn" the skin. On the other hand, calcium



rig i — rour important taboratory bases (nese common taboratory bases have made possible many of the advantages of modern life. What are some of these advantages?

hydroxide (lime water) and dilute ammonium hydroxide (ammonia water) have little corrosive action and can be applied with safety to the skin.

- Bases Have an Acrid Taste. The biting, metallic taste of a base is decidedly in contrast to the sour taste of an acid. The bitter taste in many toothpastes and in soapsuds is due to the alkali present.
- 3. Bases Turn Red Lithus Blue. Bases reverse the color change produced by acids in indicators,\* e.g., they turn red lithus paper blue and turn colorless phenolphthalein solution pink to red. This lithus test is the quickest and simplest test for a base. Other indicators, of which there are many, act similarly, e.g., methyl

<sup>\*</sup> Indicators are substances which show a decided color in the presence of soluble acids or soluble bases. An indicator, then, is a substance used to show the presence of an acid or a base in solution

orange becomes red in the presence of H<sup>+</sup> ions, and yellow in the presence of OH<sup>-</sup> ions

4 Bases React with Acids When bases react with acids, the hydroxide ion (OH-) of the base combines with the hydrogen ion (H+) of the acid to form an undissociated molecule of water, while the metal ion of the base unites with the negative ion of the acid to form a compound called a salt For example

$$Na^+OH^- + H^+CI^- \rightarrow Na^+CI^- + H_2O$$

Thus is an example of a reaction called neutralization, which will be discussed in the next chapter on salts

5 BASES REACT WITH SALTS Frequently a base will react with a soluble salt to form an insoluble base and a salt, e g,

2 Na+OH- 
$$+$$
 Ma++5O<sub>4</sub>-  $\rightarrow$  2Na+,5O<sub>4</sub>-  $+$  Mg(OH)<sub>2</sub>  $\downarrow$ 

- 6 Bases Acr on Tissues Bases dissolve proteins and react with fats to form a class of compounds known as soaps Strong bases, i. e. alkalies, destroy tissues by dissolving their albumin, reacting with the fats and extracting water. Bacteria are destroyed in the same manner. The alkalies, therefore are strong irritants and corrosive poisons. This property of dissolving and decomposing albumin and fats makes basic acting substances very useful as cleaning agents, of which ammonia, lye, and washing soda are common examples. It must be understood that like acids, bases cannot be used to clean all kinds of substances. For example, bases quickly dissolve protein material, such as wool or silk cloth. For this reason it is univase to use strong laundry soaps in washing silks or woolen material. The free base not only causes a partial destruction of woolen fabrics, but also causes such garments to shrink.
- 7 BASES REACT WITH CERTAIN METALS Some bases, especially sodium hydroxide, react with certain metals such as aluminum and zinc to liberate hydrogen and form salfs

2 AI 
$$+$$
 6 NaOH  $\xrightarrow{\text{Heat}}$  3 H<sub>2</sub>  $\uparrow$   $+$  2 Na<sub>3</sub>AIO<sub>3</sub> (sod wm olveninate)  
Zn  $+$  2 NaOH  $\xrightarrow{\text{Heat}}$  H<sub>2</sub>  $\uparrow$   $+$  Na<sub>2</sub>ZnO<sub>2</sub> (sod wm zincate)

It is because of this action that strong alkalies like lye (NaOH) or washing soda (Na<sub>2</sub>CO<sub>3</sub>) should not be used in cleaning house

hold utensils made of aluminum or coated with zinc (galvanized mon)

### Antidotes for Bases

It frequently happens that it is useful to know the antidotes for bases To neutralize bases taken internally dilute acids, such as those present in citric juices vinegar, and sour milk, are used

As in the case of acids, when bases are spilled upon clothing or skin, an attempt should first be made to remove the base by washing in running water, before attempting to neutralize it with any dilute and

### Strong vs. Concentrated Bases

Since basic properties are due to hydroxyl ions, the bases which produce a high concentration of OH- ions are strong, that is, strong bases are more highly ionized than weak bases

The term concentrated applied to a base relates to the quantity of dissolved base (solute) in the total solution. When the ratio of solute to solvent is high the solution is concentrated when this ratio is low the solution is dilute. To illustrate, concentrated am monum hydroxide solution contains a large amount of dissolved ammonia, it is, however, a weak base because there is a low concen tration of hydroxyl ions present. Weak bases, like strong ones, are completely neutralized by acids The removal of OH- ions by neutralization allows more of the undissociated molecules to ionize until finally all of the base has been acted upon

#### SELE-TESTING OUESTIONS

- 1 What is a base? an alkali?
- 2 What is a test for the hydroxyl ion?
- 3 Name six characteristic properties of all soluble bases 4 What is neutralization?
- 5 In what three ways may a base act upon the tissues? 6 How is it possible to counteract the action of a base taken internally?
- 7 What is the distinction between strong and concentrated bases?

## II TYPICAL BASES

# Sodium Hydroxide or Caustic Soda (NaOH)

When sodium reacts with water, one-half of the hydrogen is Inherated as a gas

Now if the solution is evaporated to dryness, a white compound called sodium hydroxide is left. This compound readily absorbs water, and so quickly disintegrates most vegetable and animal material that it is frequently called "caustic soda". It is sold as a household article under the name of lye, and is valuable for cleans ing purposes because it reacts with grease to make a soluble substance, soap (p. 361)

Commercial sodium hydroxide is obtained by electrolysis of a solution of sodium chloride (see p 129)

It is used in the manufacture of hard soaps, potassium hydroxide being used to make soft soaps. Sodium hydroxide is also used extensively in the manufacture of chemicals, rayon and other textiles, paper, and refining of petroleum

## Calcium Hydroxide or Slaked Lime (Ca(OH)2).

This compound is made by adding water to lime, the process being called slaking

$$CaO + H_2O \rightarrow Ca(OH)_2$$

The white compound thus formed is spanngly soluble in water and therefore gives a very low concentration of hydroxyl ons. A clear saturated solution of the calcium hydroxide in water, called limenater, is used in medicine to overcome high acidity of the stomach. It is frequently added to cow's milk in order to lessen its acidity, thereby assisting in digestion by preventing too rapid curdling which results in the formation of large tough curds. Lime water is also used in the det for building bones and teeth, as an antidote in acid poisoning (especially oxalic acid), and in the laboratory as a test for carbon dioxide, since it forms a white precipitate of calcium carbonate with the gas. A suspension of the hydroxide in water is called "milk of lime" and is extensively used as a whitewash. When so used, the calcium hydroxide grad ually absorbs carbon dioxide to form insoluble calcium carbonate

Calcium hydroxide is a moderately active base and is mexpensive to make, but its slight solubility in water prevents its use for many purposes. It is used commercially for removing hair from hides in the preparation of plaster and mortar, and as a white week

## Ammonium Hydroxide or Aqua Ammonia (NH4OH)

Ammonium hydroxide has slightly active basic properties When heated it quickly decomposes into ammonia and water

### NH<sub>4</sub>OH → NH<sub>3</sub> + H<sub>2</sub>O

Large quantities of ammonia gas are used in the manufacture of ice. For this purpose the ammonia gas is compressed to a liquid which flows through an expansion valve into long series of coils immersed in a brine solution. Metal vessels filled with pure water, are lowered into the brine solution. The liquid ammonia upon expanding absorbs heat from the brine and lowers the temperature of the brine below 0°C. The brine does not freeze but the pure water in the metal vessels is frozen into cakes of ice after a period of many hours.

If a room which serves as a refrigerator is to be kept cool, the pipes are simply run around the interior walls of the room. These cold storage plants have a temperature low enough to prevent decay and putrefaction.

In the home, ammonia dissolved in water, and known as am monia water (aqua ammonia) or ammonium hydroxide, is used in preference to other alkalies as a cleanser because any excess of the ammonia left after it is used volatilizes and produces no harm to the goods

Ammonum hydroxide, being volatile, is more penetrating but less caustic than the other alkalies Ammonia gas (NH<sub>3</sub>) stimulates both resorration and circulation Medicinally ammonium hydroxide is used as a heart and respiratory stimulant, in liniments to relieve rheumatic pains, and as an antacid

## Magnesium Hydroxide or Milk of Magnesia (Mg(OH)2)

This slightly soluble compound is a medicinal base much used as a laxative It is also used in tooth pastes and mouth washes, and to counteract too much acid in the stomach

## SELF-TESTING QUESTIONS

- 8 What properties does lye have which make it a valuable article for use in the home?
- 9 What is the chief use of sodium hydroxide?
  10 What is meant by the slaking of lime?
- 11 How is imewater made and for what is it used?

basement walks?

12 What is whitewash and why does it form a satisfactory covering for

Bases 163

13. What are the commercial and medicinal uses of aqua ammonia?

14. How is magnesium hydroxide used medicinally?

### III. HYDROGEN ION CONCENTRATION

### Hydrogen Ion Scale:

In the chapter on ionization it is stated that strength refers to the degree of ionization, whether applied to an acid or a base. In the case of an acid, the strength of its solution depends upon the concentration of hydrogen ions (H<sup>+</sup>); and in the case of a base, the strength depends upon the concentration of hydroxyl ions (OH<sup>-</sup>).

When the number of  $H^+$  ions exceeds that of the  $OH^-$  ions the solution is acid, and conversely, if there is an excess of  $OH^-$  ions, the solution is alkaline. However, when the number of  $H^+$  ions exactly equals the number of  $OH^-$  ions the solution is neutral. Thus pure water is neutral for it is dissociated into equal numbers of  $H^+$  ions  $(10.08 \ Gm.\ in 10.000,000 \ or\ 10^7\ liters of water)$ , and  $OH^-$  ions  $(17.008 \ Gm.\ in 10.000,000 \ or\ 10^7\ liters of water).$ 

The fact that purified water conducts electricity implies the following probable reaction:

the heavy arrow indicating that most of the water exists as electrical neutral particles, i.e., molecules.

Since some fluids of the body are acid, such as the gastric juice and urine, while some are alkaline, as the intestinal fluids and the blood, it is evident that any variation of acidity or alkalinity from the normal condition may be an important factor in the diagnosis of disease. To designate accurately this degree of acidity or alkalinity, that is, to express quantitatively the concentration of hydrogen ions, there has been used in recent years what has been termed the "Hydrogen Ion Scale," the symbol for which is pH.

## Meaning of pH Scale:

It is no more necessary to know the mathematical derivation of "pH"\* in order to use it, than it is to know the derivation of the term "degree Fahrenheit" when using a thermometer.

<sup>\*</sup>The logarithm of the number of liters of a solution which contains 1 008 Gm of hydrogen ions is called the pH value Sinces it takes 10,000,000 liters of water to produce 1 008 Gm of H\* one, and the logarithm of 10,000 000 s 7, the pH value of neutral water is 7 This number 7 then is the pH value for all neutral solutions For a more comprehensive treatise, refer to The A B C of Hydrogen Ion Control, LaMotte Chemical Products Co, Ballimore, Md, or any standard tertbook of general chemistry

#### Indicators:

Litmus paper has already been mentioned as useful for indicating when a solution is acid or alkline, but we know nothing therefrom about the exact degree of acidity or alkalinity. All that can be depended upon is that a deep blue or red indicates a higher degree of alkalinity or acidity than do the lighter colors. The substitution of definite pH values does away with the indefinite terms "strong" and "weak."

There are numerous dyes or "indicators" which change their colors under the influence of certain concentrations of H+ ions and OH- ions. Litmus solution, for example, shows pink color changes in an acid solution from pH 4.6 to pH 7.0, the neutral point, and then shows blue color changes in an alkaline solution up to pH 8.4. Phenolphthalein, another common indicator, shows pink to red color changes in alkaline solutions of pH numbers greater than 8.7. The wide range of these two indicators and their indistinct color changes makes them very inaccurate for determining the exact degree of acidity or alkalinity; consequently, one needs a series of indicators with short distinct color ranges to cover the entire pH scale. Fortunately, there are indicators which change colors at other degrees of hydrogen ion concentration, and by their use it is possible to determine accurately the acidity or alkalinity of solutions within a certain short range.

Of the large number of indicators available, those in the table below are chosen as representative ones with short ranges.

SOME ACID. BASE INDICATORS

	pH Range	Co	lor
Indicator	pri Kange	at Lower pH	at Higher pH
Methyl violet	01-32	Yellow	Violet
Thymol blue	13-28	Red	Blue
Bromphenol blue	30-46	Yellow	Blue
Methyl orange	31-44	Red	Yellow
Methyl red	44-62	Red	Yellow
Litmus	47-82	Red	Blue
Bromcresol purple	52-68	Yellow	Purple
Bromthymol blue	60-76	Yellow	Blue
Phenolphthalem	80-98	Colorless	Red
Thymolphthalem	9.3-10 5	Colorless	Blue
Alizarin yellow	10 1-12 1	Yellow	Red



Fig 3—A pH Meter. Here a pH meter is being used to show the hydrogen ion concentration in a solution. What does the reading on the meter indicate? Courtery Beckman Instruments. Inc.

### Testing for pH Values.

(1) COLORIMETRIC In order to determine the pH value of an unknown solution it is first necessary to select experimentally an

indicator which is sensitive, that is, shows color changes at the pH of the unknown. The table on page 166 lists indicators suitable for this purpose. It is advisable to start with bromthymol blue since this indicator undergoes color changes over the neutral point (see table). In testing a drop of the indicator is added to a small portion of the unknown, a new portion of unknown must be used for each indicator.

For example, if it is found in the preliminary testing that thymol blue is suitable, add one or two drops of this indicator solution to a sample of the unknown. The volume of unknown used, and the container should be the same as employed in the standards. Match this test sample with a set of permanent color standards made up by use of the same indicator in solutions which differ in pH in steps of 2 over the range of the indicator.

(2) Electrometric The electrometric method makes possible a more rapid and more accurate determination of the pH of a solution Also, if the solution or fluid to be tested is cloudy (turbid) or colored the colorimetric method obviously cannot be used. The two electrodes of the pH meter are dipped into the solution being examined, and the pH of the solution is then read directly from the dial of the meter (Fig. 3).

### Hydrogen Content vs. Hydrogen Ion Concentration

In neutralizing an acid with a base, all of the hydrogen in the acid reacts with a base

Such determinations are spoken of as the total hydrogen content of the acid (un ionized acid molecules + acid ions), which is quite different from the active hydrogen ion concentration or pH value Total acidity (and alkalinity in biological materials) of a solution may be compared to the total wealth of a person whereas active accidity considers only the readily available currency.

To illustrate Two acids like sulfuric and boric acids in equivalent concentration have the same total hydrogen content, but the boric acid is much weaker than the sulfuric acid, since in solution the boric acid gives only a low percentage of active H<sup>+</sup> ions The pH or hydrogen ion scale measures the actual concentration of H<sup>+</sup> ions, and not the total hydrogen content, consequently, the pH

value is a true measure of the strength of an acid or an alkali However, active acidity is not always of prime importance. For example, if only enough soda (sodium bicarbonate) is added to sour milk (lactic acid), as a leavening agent in the making of soda biscuits to neturalize the active acid, the biscuits would still have a sour taste. This condition can be corrected by adding sufficient soda to react with the total hydrogen content of the acid.

The following table shows the approximate pH values of some common 0 1N solutions of acids and of basic compounds

Acid	pH Value	Basic	pH Value
Hydrochloric	10	Sodium hydrogen carbonate	84
Sulfuric	12	Sodium tetraborate (borax)	92
Acetic	29	Ammonium hydroxide	111
Carbonic	38	Sodium carbonate	116
Boric	52	Sodium hydroxide	13 2

### Applications of pH Value to Disease:

There are many valuable applications of the pH control, especially in pathology and bacteriology. The normal pH values of the blood are between 73 and 75 and, since life becomes endangered if the values are outside the range of 70 to 78, determination of the hydrogen ion concentration is of great importance to the physician in assisting him to diagnose and treat many diseases such as diabetes, nephritis, and tetany

THE AH VALUES OF SOME FLUIDS AND SOLUTIONS

Substance	pΗ
Hydrochloric acid (0 1 N)	10
Gastric fluid	15-28
Vinegar	30
Grapefruit juice	3 2
Urine	50-75
Mılk	66-69
Saliva	68-72
Water (pure)	70
Blood	7 35- 7 45
Intestinal fluid	72-80
Pancreatic fluid	75-80

Normal gastric juice, which contains some free hydrochloric acid, is approximately one million times as acid as the blood. Here also any great deviation of Pl values has a pathological significance. For instance, in permicious anemia and in cancer of the stomach little acid may be present in the gastric juice, while in indigestion inflammation and ulcers of the stomach, the Pl1 numbers run low,  $\iota e$ , the acidity is above normal. Also, it is a well recognized fact that in abnormal variations of acid (outside of P1 13 to 40) the enzymes of the stomach are inhibited in the digestion of proteins

In the next chapter it will be learned that pH values of fluids can be maintained reasonably constant by the presence of buffers. The most important buffers in body fluids are bicarbonates and phosphates

It is clearly evident from this brief discussion that disturbances of the hydrogen ion concentration of any fluids in the body are an indication of some pathological disturbance

#### SELE-TESTING QUESTIONS

- 15 What is the hydrogen ion scale used for?
- 16 What is meant by pH values?
- 17 What does pH 70 mean?
- 18 When does a pH reading indicate acidity?
- 19 In what way do pH values indicate strong and weak acids or bases?
  20 Name two common indicators and their color in both acid and alkaline
- solutions
  21 How would you proceed to make a test for pH values?
- 22 How does hydrogen content differ from hydrogen ion concentration?
- 23 Give a pathological application of pH significance
- 24 Given the pH of a solution how is the pOH determined?
- 25 Measuring the hydrogen ion concentration of a solution by the colori metric system depends upon what principle?

#### SUGGESTED ACTIVITIES

- I THOUGHT PROYOKING QUESTIONS
  - 1 Why is lye sold in tin containers? Why would not aluminum containers be practicable?
    - 2 Sodium stearate NaC13H35O2 is a soap How would this solution react to htmus? Explain
    - 3 Account for the fact that calcium hydroxide when dry has no effect upon red litmus paper
    - 4 To counteract or neutralize and spilled on clothing why is am monium hydroxide used in preference to sodium hydroxide?

      5 Explain why borax solution shows an alkaline reaction to litmus
    - paper 6 Solution A has a pH of 30 and solution B has a pH of 60 What is
    - 6 Solution A has a pH of 30 and solution B has a pH of 60 What is the relationship between their actual hydrogen ion concentrations?

- 7 What is the pH value when the hydrogen ion concentration is 0 0001 gram ions per liter?
- 8 What is the pH of an acid which has one hundred times the acidity of water?
- 9 To counteract the action of large quantities of acid spilled on the laboratory floor or table, why is sodium hydrogen carbonate generally used instead of ammonium hydroxide?
- 10 Using the adverbs faintly, weakly, and strongly, interpret the condition of acidity or alkalinity of the following solutions pH 75, 13, 13, 52, 29, 84
- 11 In many pathological conditions the hydrogen ion concentration of the urine is increased. Is the pH value raised or lowered?
- II. Vocabulary Testing of New Terms
  base neutralization
  alkali hydrolysis

ındıcator pH scale

#### III Topics for Oral or Written Reports

- 1 Antidotes for Alkalı Poisoning
- 2 Indicators and pH Measurements
- 3 Acid and Alkalı in Health and Disease
- 4 The pH of Body Fluids and Tissues

### LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on pages 679, 681 684

#### CHAPTER IX

#### SALTS

#### CHAPTER OUTLINE

- I PREPARATION AND PROPERTIES
  (a) Neutralization
  - (a) Neutranzation (b) Preparation of salts
  - (b) Preparation of salts
    (c) Incompatibility of some salts
    - (d) Properties of salts
    - (e) Ionization of salts (f) Typical salts
- II TYPES AND NAMES OF SALTS
  (a) Normal, acid, and basic salts
- (b) Naming of salts
- III Hyprolysts of Salts
  (a) Why some salt solutions are not neutral

- (b) Sodium hydrogen carbonate
- IV BUFFERS IN THE BLOOD
  - (a) Buffer action in the blood
  - V SALTS IN THE HUMAN BODY
    - (a) Formation of salts(b) Chemical balance of the body
    - (c) Importance of salts in the body (d) Effects of salts on the cells
- VI ALKALOM SALTS
  - (a) Properties of alkaloids
    - (b) Antidotes



Fig 1—Household Salts Can you name one or more medical uses for any of these salts? Courtesy, Raymond Fearon, Philadelphia

# I. PREPARATION AND PROPERTIES

## Neutralization:

When solutions of an acid and a base are brought together in the proper proportions, the characteristic properties of both are lost, e.g., there is no effect of the mixture upon either blue or red litmus paper. From this fact we infer that the hydrogen ions of the acid and the hydroxyl ions of the base must have been removed from the solution. An examination of the following equation

$$N\alpha^+OH^- + H^+CI^- \rightarrow N\alpha^+CI^- + H_2O$$

shows that the negative hydroxyl ion of the base has combined

with the positive hydrogen ion of the acid to form undissociated water, while the remaining part of the base (Na\*) has combined with the remaining part of the acid (Cl-) to form one of the class of compounds which we call salts. Such a reaction between an acid and a base with the formation of a salt and water is known as neutralization. Upon evaporating the solution the concentration increases and the sodium and chloride ions begin to join together, and the solid salt crystalizes out of solution, once the saturation point is exceeded.



Fig 2—An American Salt Mine Common salt is obtained from mines or by evaporation of water. For what purposes a salt needed by the body? Courtery, International Salt Company, Inc.

Since there are many acids and base-forming substances in nature, and since acids and bases are very active chemically, salts are constantly formed in the crust of the earth. These saits are also undergoing a decomposition to form new compounds. It is also true that from one salt may be formed an acid, which in turn may react with another salt to form still different compounds. Thus common salt upon treatment with sulfuric acid will produce hydrochloric acid:

The hydrochloric acid then may decompose another salt to form still another acid and another salt, as shown by the following equations

$$CaCO_3 + 2 HCI \rightarrow CaCl_2 + H_2CO_2$$
  
 $H_2CO_3 \rightarrow H_2O + CO_2$ 

# Preparation of Salts.

From the preceding paragraph it is evident that a salt may be formed by the union of an acid and a base or by the action between certain acids and various salts. A soluble salt may also be formed by the action of an acid upon a metal, its oxide, hydroxide, or its carbonate as illustrated in the following equations.

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$$
  
 $ZnO + H_2SO_4 \rightarrow ZnSO_4 + H_2O$   
 $Zn(OH)_2 + H_2SO_4 \rightarrow ZnSO_4 + 2 H_2O$   
 $ZnCO_3 + H_2SO_4 \rightarrow ZnSO_4 + H_2O + CO_2$ 

These reactions you may recall as typical of acids (p 145) A salt, then, is a combination of a metal, or the metallic radical NH<sub>4</sub>, with a nonmetal or nonmetallic radical of an acid, as Cl, Br, SO<sub>4</sub>, NO<sub>2</sub>, and PO<sub>4</sub>

## Incompatibility of Some Salts:

Salts may also be formed by several other methods, one of which is worthy of mention, namely the reaction between two soluble salts. Salts formed in this way are often insoluble,  $e \ g$ , in the following equation silver chloride is an insoluble salt.

As a therapeutic measure a solution of the salt silver nitrate is often used in bladder infections. Soon, however, the germicidal action of the silver nitrate is stopped, as the sodium chloride in the urme reacts with the silver intrate to form insoluble silver chloride. Again, as a prophylaxis against gonorrheal infection, most states require that a drop of 1 to 2 per cent solution of silver nitrate be placed in the eyes of newborn babies. In this instance, the salty tears, or the use of a physiological saline solution, stops the further action of the silver nitrate on the tissue cells of the eyes. As another example, potassium iodide forms an insoluble salt when used

internally as a treatment for lead poisoning. As two salts may react to form new salts with different properties you can understand why it is seldom a good idea to administer two salts at the same time. The properties of the new salts might do more harm than good.

From these statements it is evident that a nurse should be aware of the fact that many salis, and other compounds, for that matter, are incompatible. The incompatibility of a number of pairs of compounds follows

#### SOME COMMON INCOMPATIBLES

Magnesium sulfate and Ferric chloride Sodum hicarbonate and Ammonium chloride Sodum bicarbonate and Ferre chloride Sodium bicarbonate and Limewater Sodium bromide and Ferric chloride Sodium chloride and Silver nitrate Calcum chloride and Ephedrine Ferrous iodide syrup and Quinine or codeine Magnesium sulfate and Quinine Potassum iodide and Strychnine sulfate

Sodium bicarbonate and Ephedrine hydrochloride
Sodium salicylate and Caffeine citrate

# Properties of Salts

In studying acids and bases we study respectively the hydrogen ion (H+) and the hydroxyl ion (OH-), but in examining the for mulas of such salts as silver nitrate (AgNO<sub>3</sub>), mercuric chloride (HgCl2), or magnesium sulfate (MgSO4), we see that there is no ion that is common to all salts. For this reason we are unable to list a number of properties common to all salts as we did in the case of acids and bases. For instance some salts taste sour some alkaline, others salty or metallic, and a few even taste sweet We also may find that salts vary in their action toward indicators, some being acid some alkaline, and some neutral It is even true that a few salts are oxidizing agents (chlorates, nitrates perman ganates) while others combine with oxygen and with sulfites and therefore are reducing agents. Nevertheless we do find similarities in such physical properties as color, taste and solubility Especially is this true between certain salts of the same metal (NaCl Na2SO4, NaNO3) or between various salts of the same acid (NaCl, KCl, NH<sub>4</sub>Cl)

The chemical reactions of some salts with other salts (p 175), with water (hydrolysis) to form acids and bases (pp 182, 183), with acids (p 175), and with bases (p 175) have already been stated Reactions of salts with metals to form another salt and another metal have been mentioned (p 146) and the discussion of salt and metal contacts that are to be avoided in laboratory, hospital, and household practice is presented later on under the subject of metals (p 215)

# Ionization of Salts:

As has been stated (p 133), most salts are strong electrolytes, that is, they are highly ionized As a consequence, reactions between salt ions usually are rapid. Some salts though, like mercuric chloride, only slightly ionize and consequently react slowly in solution. The degree of ionization in the case of electrolytes represents the ratio of free ions to the unionized molecules, or to associated ions. Notice in the following table that the percentage of ionization in a N/10 solution of most salts ranges from 65 to 85 per cent

Types of Salts	Percentage of Ionization in a N/10 Solution
M+1 A-1 (eg, NaCl)	83 to 86
M+2 A-1 (eg. BaCl2)	72 to 77
M2+1A 2 (eg, Na2SO4)	70 to 73
M+2 A 2 (e.g., ZnSO4)	50 to less

# Typical Salts

Of the many hundreds of salts, several that are widely used in industries are common salt (NaCl), washing soda (Na<sub>2</sub>CO<sub>3</sub> 10 H<sub>2</sub>O), limestone (CaCO<sub>3</sub>), and Chile saltpeter (NaNO<sub>3</sub>) How ever, there are many other important salts, some of which are used quite extensively in medicine (Fig. 3) The following salts of the four common acids HCl, H-SO<sub>4</sub>, HNO<sub>3</sub> and H<sub>2</sub>CO<sub>3</sub> are so fre quently used in medicine that a brief discussion of them is given on the next page

Since there are so many salts, space does not permit us to make an individual study of them or even to mention all of the important ones, however, a detailed study of medicinal salts is given in Pharmacology

# MEDICINAL SALTS OF SOME COMMON ACIDS

Salt	Common Name	Use
Sodium chloride (NaCl)	Table salt	Saline solution
Mercurous chloride (Hg <sub>2</sub> Cl <sub>2</sub> )	Calomel	Purgative
Mercuric chloride (HgCl <sub>2</sub> )	Corrosive sublimate	Antisepticandantisyphilitic
Magnessum sulfate (MgSO <sub>4</sub> • 7 H <sub>2</sub> O)	Epsom salts	Purgative Allays inflam mation
Barium sulfate (BaSO.)  Calcium sulfate	"Barium" Plaster of Paris	Coats the stomach and in testines with a compound, opaque to the x ray Casts for broken bones
(CaSO <sub>4</sub> ) <sub>2</sub> · H <sub>2</sub> O		
Potassium nitrate (KNO <sub>3</sub> )	Saltpeter	Diuretic
Silver nitrate (AgNO <sub>3</sub> )	Lunar caustic	Antiseptic caustic, astrin
Bismuth submitrate (BiONO <sub>3</sub> · H <sub>2</sub> O)	"Bismuth"	Anti irritant of the bowels, astringent
Ammonium carbonate [(NH <sub>4</sub> ) <sub>2</sub> CO <sub>3</sub> H <sub>2</sub> O]		Stimulant in syncope, ex pectorant in bronchitis
Bismuth subcarbonate $(Bi_2O_2CO_3)$		Antacid, in roentgenog raphy
Calcium carbonate (CaCO <sub>3</sub> )	Precipitated chalk	Antacid, detergent, protec- tive in gastric ulcer
Ferrous carbonate (FeCO <sub>3</sub> )		In anemia (in the form of Blaud's pills)
Magnessum carbonate (MgCO <sub>3</sub> )		Antacid, in hyperacidity, dusting powder, cosmetic
Sodium bicarbonate (NaHCO <sub>3</sub> )	Baking soda	In hyperacidity, in scidosis, alkaline wash
Sodium carbonate (Na <sub>2</sub> CO <sub>2</sub> · 10 H <sub>2</sub> O)	Washing soda	Preparation of alkaline baths



Fig 3—X ray Therapy Machine This 2 000 000 volt x ray machine makes possible a scientific treatment of deep seated malignancy. For what disease would this unit find its widest use? Courtesy, General Electric Company

# SELF-TESTING QUESTIONS

- 1 What is always formed in neutralization?
- 2 What are five general methods of preparing salts?
- 3 What might be the danger of administering different salts at the same time?

- 4 Why do not salts have common properties?
- 5 State the chemical name the common name and a medicinal use of three important chlorides sulfates nitrates and carbonates

## II. TYPES AND NAMES OF SALTS

#### Normal, Acid, and Basic Salts:

If an acid has more than one replaceable hydrogen atom\* per molecule it is possible to make two salts, depending upon the amounts of base used The following examples illustrate this

acid salt formation 
$$NaOH + H_2CO_3 \rightarrow NaHCO_3 + H_2O$$
 normal salt formation  $2 NaOH + H_2CO_3 \rightarrow Na_2CO_3 + 2 H_2O$ 

The one salt  $(NaHCO_3)$  still retains one atom of hydrogen, since there are not enough hydroxyl ions to unite with all of the hydrogen In forming the second salt  $(Na_2CO_3)$  all of the hydrogen of the acid is displaced by the metal sodium. The former salt is known as an acid salt and is called sodium hydrogen carbonate (baking soda), while the latter  $(Na_2CO_3)$  is a normal salt and is called sodium car bonate (washing soda)

Similarly there are produced hydroxy or more commonly called basic salts, when only part of the hydroxyl ions of a base are replaced by a nonmetal or a nonmetallic radical as for example

$$B_1(OH)_3 + HNO_3 \rightarrow B_1(OH)_2NO_3 + H_2O$$
  
 $B_1(OH)_3 + 2 HNO_3 \rightarrow B_1OH(NO_3)_2 + 2 H_2O$ 

When a hydroxy salt as basic bismuth nitrate (Bi(OH)-NO<sub>3</sub>) is dried, it loses a molecule of water to form bismuth subnitrate or oxynitrate, BiONO<sub>3</sub>, a white insoluble compound, called an oxy salt Bismuth subnitrate acts upon the mucous membranes of the stom ach and intestines much like a face powder does upon the skin, and as a consequence is used to coat, protect, and heal ulcers of the intestinal tract Moreover, this salt is also used like barums sulfate in making x ray pictures of the digestive tract Bismuth subnitrate can act as an alkali to neutralize the acid of the stomach and in this way is said to "sweeten" an acid stomach

The use of the terms acid, basic, and normal in classifying salts is to point out the composition or structure of each salt, not its

<sup>\*</sup> Replaceable hydrogen of an acid refers only to the hydrogen capable of forming ions In the case of organic acids as will be shown later not all of the hydrogen is replaceable

behavior toward an indicator Thus sodium bicarbonate (NaHCO3) is classified as an acid salt, but in water solution this salt gives an alkaline test with litmus paper. The reason for this is given later in this chaoter.

# Naming of Salts:

Salts are named from the metal and the acid from which they are derived A salt of a binary acid, i.e., an acid containing one other element besides hydrogen, is given the name of the two elements composing it, with the ending "ide". Thus NaCl is read "sodium chloride". The ending "ate" is used for the names of salts of ternary acids which end in ic. If the name of the ternary acid ends in ous, the ending of the salt is "the". Thus Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfuric acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub>2</sub>SO<sub>3</sub>, a salt of sulfurious acid, is named sodium sulfate, while Na<sub></sub>

Formula	Sodium Salt
NaClO <sub>4</sub> NaClO <sub>3</sub> NaClO <sub>2</sub> NaClO NaCl	Sodium per chlor-ate Sodium chlor ate Sodium chlor ite Sodium hypo chlor ite Sodium chlor ide
	NaClO <sub>2</sub> NaClO <sub>2</sub> NaClO

Acid salts are distinguished by the word hydrogen or acid, or by the prefix bi, eg,

the prefix bi, e g, NaHCO<sub>3</sub> (Sodium hydrogen carbonate Sodium bicarbonate

The use of bi (above) is somewhat confusing as in some compounds it means two Thus  $\mathrm{HgCl}_2$  is frequently called bichloride of mercury If more than one metallic atom replaces hydrogen, as in a tribasic acid, the following nomenclature should be used

> NaH<sub>2</sub>PO<sub>4</sub> Monosodium phosphate Na<sub>2</sub>HPO<sub>4</sub> Disodium phosphate Na<sub>3</sub>PO<sub>4</sub> Trisodium phosphate

Basic salts usually contain the word basic in their names, or less often they contain the prefix sub, thus

# Bi(OH)<sub>2</sub>NO<sub>3</sub> Bismuth subnitrate Dibasic bismuth mirate

Mixed salts formed by more than one metal replacing hydrogen of acids are named thus

# KNaC4H4O6 Potassium sodium tartrate

Double salts result when two different salts crystallize simultaneously from one solution to give crystals which contain both salts in a definite proportion. The alums, such as potash alum,  $K_2SO_4$   $Al_2(SO_4)_3$  24  $H_2O$  are examples

# SELF-TESTING QUESTIONS

- 6 What is a normal salt an acid salt and a basic salt?
- 7 Name and give an important use of a normal acid and have salt
- 8 How are salts of ternary soids named?
- 9 May an acid salt be alkaline in solution?
- 10 State the names and formulas of the sodium salts of five acids which
- 11 How are acid basic and mixed salts named?
- 12 In what way does the double salt differ from the mixed salt?
- 13 What is the rule for naming salts of binary acids?
- 14 What are some medicinal uses for bismuth submitrate?

## III HYDROLYSIS OF SAITS

Water has been previously characterized as a nonelectrolyte and nonconductor of electricity, but very careful measurements reveal that the purest of water has a very slight ionic dissociation (0 0000018 per cent) into hydrogen ions and hydroxyl ions. This fact helps to explain why aqueous solutions of certain salts are not neutral.

## Why Some Salt Solutions Are Not Neutral

If one prepares water solutions of a variety of normal salts it will be found that some show an acid reaction to litimus others an alkaline reaction and still others a neutral effect. Since normal salts contain neither hydrogen nor hydroxyl radicals they cannot in themselves be directly responsible for the acidic and the basic solutions. The fact that some normal salts in water solution are

acidic while others are basic is explained in terms of reactions of ions of the salts with water. This type of reaction of a salt, involving water, is called salt hydrolvsis.

Sodium carbonate is typical of those salts whose water solutions are basic. A solution of this salt consists of sodium ions and carbonate ions. It has been pointed out that water itself is only slightly ionized. The following equations express these facts.

$$N\alpha_2CO_3 \rightarrow 2 N\alpha^+ + CO_3^-$$
  
2 HOH  $\rightleftharpoons 2 OH^- + 2 H^+$   
 $H_2CO_3$ 

The hydrogen ions and carbonate ions combine to a considerable degree to give the weak, molecular carbonic acid As a result of this, hydrogen ions are withdrawn Sodium ions and hydroxyl ions show no tendency to combine, recall that sodium hydroxide is a strong base, and in water may be viewed as completely ionic Hence there will be in the solution a higher concentration of hydroxyl ions than hydrogen ions, and consequently the solution is basic and turns red litmus paper to blue Notice that the sodium carbonate is a salt which is derived from a strong base (NaOH) and a weak acid (H<sub>2</sub>CO<sub>3</sub>)

An opposite effect is obtained with the salt ammonium chloride In water this salt exists as freely moving ions

Here we notice that hydroxyl ions and ammonium ions combine extensively to form the weak, molecular ammonium hydroxide This consumes hydroxyl ions. The chloride ions and hydrogen ions do not combine masmuch as hydrochloric and is a strong, highly ionized electrolyte. The result is that the concentration of hydrogen ions in the solution is higher than the concentration of the hydroxyl ions, and consequently the solution reacts acidic

Salts like sodium chloride, which are derived from strong acids and strong bases, do not hydrolyze, hence they form solutions which are neutral Those salts which are derived from weak acids and weak bases, for example, ammonium carbonate, are extensively



Fig. 5—Alkaline Producing Foods. Same of these foods have an acid taste. Still they are base forming in the blood. To what classes do most alkaline producing foods belong?

# Chemical Balance of the Body:

When foods are burned outside of the body an acid or a basic ash may be obtained. Consequently when oxidized in the body, they may be considered as either acid forming or base forming foods (Figs. 4, 5). In general, the acids of fruits are so oxidized in the body that an alkaline ash results. On the other hand, some foods such as creals and meat, which do not have an acid taste, yield acidic substances when they are digested.

The blood and the tissues are slightly alkaline, a condition which prevents an accumulation of acids in the body. The kidneys, too, function in removing acids and thereby help maintain the alkalinity of the blood stream (p. 484). The excess of alkali (mostly due to sodium bicarbonate) over the acid in the blood is known as the alkaline reserve, and this margin, though very small, is vitally important and is called the "chemical balance."

To keep the individual healthy, efficient, and to maintain his physical endurance, the blood must preserve this margin of alkalinity. As a guide to building up this chemical balance, some of the common foods have been classified on the next page.\*

# Importance of Salts in the Body:

Salts do not furnish heat or energy, yet they are very essential to life. We will learn later that in, general, salts (1) are necessary for protoplasm, tissue, and body structure; (2) maintain the elasticity and irritability of the muscles and nerves; (3) maintain the neutral or slightly acid or alkaline condition of the body fluids and (4) assist in maintaining normal osmotic pressure condition; (p. 532).

<sup>•</sup> Chemistry of Foods and Nutrition, Sherman, The Macmillan Co.

#### ALKALI-PRODUCING FOODS

These foods should be used in adequate amounts to maintain the favorable alkaline balance of the body

Degree of Alkalinity

	per 100 Gm
Almonds	12 38
Apples	3 76†
Asparagus	0 81
Bananas	5 56†
Beans dried	23 87 †
Beans, hma, dried	41 65
Beets	10 86
Cabbage	4 34
Cantaloupe	7 47 †
Carrots	10 82
Cauliflower	5 33
Celery	7 78
Chestnuts	7 42
Currents, dried	5 97
Lemons	5 45
Lettuce	7 37
Milk, cow's	2 37
Oranges	5 61
Peaches	5 04
Peas, dried	7 07
Potatoes	7 19†
Radishes	2 87
Raisins	23 68
Turnips	2 68

#### ACID-PRODUCING FOODS

These foods should always be bal anced by adequate amounts of alkalune fonda

Degree of Acidity

per 1	r 100 Gm	
Bread, white	71	
Bread whole wheat	73	
Corn, sweet, dried	5 95	
Crackers	7 81	
Crapberries .	1	
Eggs	11 10	
Egg white	5 24	
Egg yolk	26 69	
Fish haddock	16 07	
Fish, pike	11 81	
Meat, beef, lean	13 91	
Meat chicken	17 01	
Meat, frog	10 36	
Meat, rabbit	14 80	
Meat, veal	13 52	
Meat pork, lean	11 87	
Oatmeal	12 93	
Oysters	30 00	
Peanuts	3 9	
Prunes, plums	1	
Rice	81	

The following foods have neither chemical reaction Sugar

Butter Cream Starch hral

† These foods have been found experimentally to be very efficient in reducing the body acidity

I The ash of these fruits is alkaline but because of substances that form hippuric acid in the body they increase the acidity of the urine

In general all fruits vegetables nuts and milk are alkaline in the body

Of all the sources of mineral salts needed by the body, milk ranks first (p 603) It contains the balanced quantity of all the salts (iron excepted), which are needed for growth of tissues, and strong bones and teeth Of particular importance in milk is the salt, calcium hydrogen phosphate Green leafy vegetables, fruits, eggs, and whole cereal products are also excellent sources of mineral salts

Each salt has an important and special function in the body. The blood, for example, is practically a 1 per cent solution of salt and water containing the corpuscles. Albumin and sugar are also present in the solution.

Iron in the hemoglobin molecule gives color to the blood. The amount of iron in the body is only about 0 004 per cent of the weight of a person, an amount equivalent to a shingle nail. However, this very small amount of iron is of the greatest importance to life. If the foods do not contain sufficient iron, then the lowered production of hemoglobin may result in anemia, lowered vitality, and insufficient oxidation in the cells.

Sodium chloride is an essential salt in the body, as the hydro chloric acid which is necessary in the gastric juice for digestion is made from it. The presence of salt in the fluids which hathe the tissues assists in maintaining the comotic equilibrium. It is the salt in the blood which stimulates the action of the heart muscle A lack of salt slows the heart's action, a condition evidenced by low blood pressure. Since excretion of common salt in sweat is so great, it is a common practice to restore the salt lost by perspiring laborers, or by patients with an unusually high fever (hyper thermia), by giving them salt tablets (NaCl), along with conious amounts of water. In meats, sodium chloride is present in sufficient. quantities to balance the potassium, calcium, and magnesium salts Plants, however, do not provide enough sodium chloride, and as a result herbivorous animals seek salt licks in order to maintain the necessary chemical balance Too much salt in food may interfere with absorption and the utilization of food, while an excessive amount may cause death In human nutrition, salt is used primarily to make more appetizing a larger variety of foods, especially the vegetables

Sodium ions determine the amount of water held in the tissues, too high a concentration of sodium ions causing too much water to be retained, a condition known as edema or dropsy Conse quently in cases of water retention (edema) sodium chloride is restricted in the diet, and sodium free saft substitutes (KCI, NH<sub>4</sub>CI, Ca<sub>3</sub>(PO<sub>3</sub>)) are used

Calcium salts give rigidity and firmness to the bones. A lack of these salts produces poor teeth and rickets in children (see p 593) Calcium salts are absolutely essential for the clotting of the blood and they are often administered as drugs in certain diseases or Salts

prior to certain operations to assist the clotting properties of blood It is the calcium salts which partially cause contraction of the cardiac muscle, while the sodium and potassium salts cause relaxa tion The normal beating of the heart requires that the fluid bathing its muscles contain the proper proportion and concentration of calcium, sodium, and potassium ions. Metallic ions furnish the hydroxides which neutralize the acids produced by body activity It is highly important that the acidity (lactic acid) of a cell does not increase too much, for then its activity is lessened as recognized by the sense of fatigue Sometimes this overacidity causes a swelling of the tissues, since the colloidal material of the cell adsorbs more water in the presence of an acid. As has been previously stated, in the case of all salts of organic acids, e g, citrate of magnesia, the acid radicals are oxidized in the body to carbon dioxide and water, which reactions leave the metallic ions free to act as baseforming substances

## Effects of Salts on the Cells:

The moment salts enter the alimentary tract they begin to with draw fluid from the cells by osmosis, sometimes in sufficient quantity to distend the intestines and cause bowel movement. Part of the salts, however, is absorbed and carried by the blood to the cells which are bathed by the lymph. If the percentage of salt in the lymph is greater than in the cells, water is withdrawn from the cells. In case the percentage is less, the cells absorb water from the lymph, a process called "diffusion" Diffusion differs from osmosis in that it occurs without the intervention of an animal membrane. It may now be understood how the activity of certain organs such as the kidneys may be increased by certain salts.

Such metallic salts as those of mercury, iron, and arsenic are absorbed and form insoluble compounds with the proteins of the cells. If there is an excessive amount of these salts the cells are irritated, injured, and they show symptoms of poisoning. The functioning of salts in helping to regulate body processes and to make possible normal metabolism is presented on pages 526 531

#### SELE-TESTING QUESTIONS

- 28 In what four ways are salts essential to life?
- 29 What are the functions of the following salts in the body iron salts, sodium chloride calcium salts?
- 30 How do certain salts activate the kidneys?

# VI. ALKALOID SALTS

# Properties of Alkaloids

Certain nutrogenous compounds of both vegetable and animal origin act like alkalies in combining with acids to form sails. These compounds are called alkaloids, meaning alkali like With a single exception, the alkaloids are derived from plants belonging to the dicotyledons, and in some cases the same plants contain several alkaloids. The liquid alkaloids (as pilocarpine, nucture and contine)

# SOME IMPORTANT ALKALOIDS AND THEIR USES

Name	Source	Uses
Cocaine C16H21NO4	Coca leaves	Local anesthetic but being extremely toxic has been largely replaced by Novocain
Codeine CisH21NOs	Оршт	Sedative Similar but less powerful than morphine
Morphine C17H19NO3	Орниш	Sedative narcotic hypnotic Relieves pain Used with scopolamine in twilight sleep
Quinine C20H29N2O2	Cinchona bark	Specific in malaria Reduces fever Tonic or bitter to stimulate the appetite
Strychnine C21H22N2O2	Nux vomica	Stimulates the brain and spinal cord A heart and respiratory stimulant in col- lapse Tonic
Nicotine C10H14N2	Tobacco (0 6 to 8 0%)	Stimulates nervous system Causes weak pulse nauses and vonuting
Pilocarpine C <sub>11</sub> H <sub>18</sub> N <sub>2</sub> O <sub>2</sub>	Pilocarpus	Increases perspiration Acts like nicotine
Atropine C <sub>17</sub> H <sub>25</sub> NO	Deadly night shade	Secretory depressant Dilates the pupil Used in ophthalmic surgery
Brucine C23H25N2O4	Nux vonues	Physiologically one twenty fourth as strong as strychnine
Heroin C21H22NO5	Derivative of morphine	Similar to morphine Used as sedative and to lessen coughing
Emetine CacH4cN2Os	Ipecac	Treatment of amebic dysentery, and pyor rhea

have a disagreeable odor Both the liquid alkaloids and the white crystalline, solid alkaloids (as quinine, atropine, strychnine, mor phine, codeine, and cocaine) have a strong, bitter taste and many are extremely poisonous

Of the large number of vegetable alkaloids, only a very few have been prepared synthetically. The first five in the table on page 192 are commonly used in medicine. Atropine and cocaine have been largely replaced by artificial alkaloids.

Since many of the alkaloids are insoluble in water, their soluble salts are commonly used in medicine. For example, strychnine reacts with sulfuric acid to form strychnine sulfate, a soluble salt. In the same way morphine sulfate and other soluble alkaloidal salts are made. Alkaloids may be given hypodermically as well as by mouth, and since their effect occurs chiefly after entering the blood stream it is obvious that only the soluble salts are used.

#### Antidates:

Alkaloids are frequently dispensed as drugs in the hospital owing to their very energetic physiological action upon the body. Con tinued use makes some of them habit forming drugs, while an over dose may prove very toxic. Since the alkaloids and their salts are precipitated by tannic acid or potassium permanganate and are made incapable of absorption, these and other so called alkaloidal reagents are used as antidotes in alkaloid poisoning cases. The alkaloids are not easy to identify, but as a class they may be precipitated by phosphomolybdic and phosphotungstic acids, and in some cases may be identified by color reactions with sulfuric acid and an oxidizing agent.

#### SELF-TESTING QUESTIONS

- 31 What does alkaloid mean?
- 32 What are three liquid alkaloids?
- 33 State a use of the five most important alkaloids in medicine
- 34 Why are the salts rather than the pure alkaloids used in medicine?
- 35 What two reagents are antidotes for alkaloid poisoning?

# SUGGESTED ACTIVITIES

- I THOUGHT PROVOKING QUESTIONS
  - 1 Neutralization is the reverse of what other type of chemical change?
    - 2 What are the most important sources of some of the different salts needed in the body?
      - 3 Why is it that carbonic acid and not mitric scid can form acid salts?
    - 4 Why is there danger connected with the use of alkaloids?

5	Explain why orange juice,	or a small dose of sodium hydrogen
	carbonate, is frequently u	sed in the treatment of colds
6	Complete the following equa	tions
	HCl + NaOH	<b>→+</b>
	HCl + Ca(OH)2	→+
	HCl + Bi(OH);	+

- Give the formula of an acid sait of suituric acid, and of phosphoric acid (H<sub>3</sub>PO<sub>4</sub>)
   State the chemical name of the following compounds and classify
- each as to whether it is an acid, base, normal sait, scid salt, or basic salt (a) K<sub>2</sub>CO<sub>3</sub> (e) ZnSO<sub>4</sub> (i) KHC<sub>4</sub>H<sub>4</sub>O<sub>6</sub> (cream of tartar)
  - (b) Cu(OH) 2 (f) Na2HPO4 (f) Na2B4O7 (borax)
  - (c) NH<sub>4</sub>Cl (g) HClO<sub>3</sub> (k) NaHCO<sub>3</sub> (baking soda) (d) HNO<sub>3</sub> (h) NH<sub>4</sub>HCO<sub>3</sub> (l) Pb(OH)<sub>2</sub>·2 PbCO<sub>3</sub> (white
- lead)
  9 How does a solution of the acid salt, sodium hydrogen carbonate, react with litmus paper?
- 10 When will an acid salt react as an acid toward litmus paper?
- 11 How do you account for the fact that of the two acid salts disodium acid phosphate, Na<sub>2</sub>HPO<sub>4</sub>, and monosodium acid phosphate, NaH<sub>2</sub>PO<sub>4</sub>, one is alkaline acting in the blood and one is acid acting?
- 12 A patient has been taking cold tablets which frequently contain some alkaloid She feels chilly and drinks a cup of hot tea or coffee Why shouldn't this be done?
- 13 Two soluble salts react to form two new soluble salts How may the newly formed salts be separated?
- 14 Of the three sodium phosphates, which is acid which slightly alkaline, and which very alkaline?
- 15 How do you account for the constant pH value of the blood even though the amount of acid received varies considerably?

II VOCABULARY TESTING OF NEW TERMS
salt normal salt "ide"
diffusion acid salt 'hypo"

alkaloid basic salt "ate" huffer "ite' alkaline reserve "hyper "

- III Topics for Oral or Written Reports
  1 Use of Common Salt in the Body
  - 2 The Alkaloids
  - 3 Incompatibility of Certain Medicinals
  - 4 Importance of Minerals in the Diet

#### LABORATORY CHEMISTRY

#### CHAPTER X

#### NONMETALS AND METALS

#### CHAPTER OUTLINE

- I NITROGEN AND ITS COMPOUNDS

  (a) Occurrence and properties of
- nitrogen

  (b) Nitrogen essential to plant life
  - (c) Uses of nitrogen
- (d) Compounds of nitrogen
- II HALOGENS, SULFUR, PHOSPHORUS
  - (a) The halogens (b) Sulfur
    - (c) Phosphorus
- III. CARBON AND ITS COMPOUNDS
  - (a) Natural forms of carbon
  - (b) Chemical properties

- IV OXIDES OF CARBON
  - (a) Carbon dioxide (b) Carbon dioxide-oxygen
  - cycle
  - (c) Carbon monoxide V Merals
    - (a) Classifying elements as metals (b) Listing met is according to
      - activity
        (c) Tarnishing of metals
    - (d) General methods of removing tarnish
    - (e) Cleaning of some common metals
- VI ALLOYS OF METALS
  - (a) Nature of alloys (b) Properties of alloys
- \_\_\_\_\_

# I. NITROGEN AND ITS COMPOUNDS

About seventy of the elements are base forming and as such are called metals Calcium, for example, is a base-forming element, since its oxide unites with water to form the base, calcium hydroxide

The remaining elements, with their general properties somewhat the opposite of metals, have acid-forming properties and are called nonmentals \* Sulfur, for example, is an acid forming element since its oxide unites with water to form sulfurous acid

$$H_2O + SO_2 \rightarrow H_2SO_3$$

Before taking up the study of some of these elen ents, in order to have some idea of the general differences between metals and nonmetals, the following comparison is given

<sup>\*</sup>From the electron standpoint, an element which loses electrons is left positively charged and is called a metal, while any element which gains electrons is called a non metal. Some elements, and especially those having three to five valence electrons may act as metals or as nonmetals. Such elements are said to be umphoteric. For instance, their origies under some conditions may be actic and under others may be sufficient.

Nonmetale

(Fe Cu, Hg, Ag, etc)	(O, N, P, Br, etc)
Solids (except Hg)	Mostly gases (or brittle solids)
Opaque, with mirror like surfaces	Mostly transparent
Malleable, ductile	Not very malleable or ductile
Good conductors of heat	Poor conductors of heat
Good conductors of electricity	Poor conductors of electricity
Base formers	Acid formers
Lose electrons to form + 10ns	Gain electrons to form - 10ns

# Occurrence and Properties of Nitrogen:

Motals

The mert gas nitrogen makes up about four fifths of the air and is of great importance, since it is indirectly essential to life and is present in all living matter, both animal and vegetable. In the combined state, nitrogen is found in only a few mineral compounds (NaNOa, KNOa), and most of these compounds have been produced by plant or animal life Proteins, which form a valuable constituent of our foods, are nitrogen compounds. In fact, nitrogen is the principal element in the living cell

Nitrogen, like oxygen and hydrogen, is a colorless, odorless, tasteless gas, but differs in its chemical action in that it is not active at

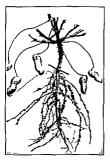


Fig 1-Multiplying Bacteria at Work. Ob serve the nodules formed by the n tragen fixing bacteria which convert free nitrogen of the air into soluble nitrates. The pea nuts are used for what purposes? Courlesy, U.S. Dent of Agriculture

ordinary temperatures At high temperatures, however, introgen does combine directly with a few elements to form a class of compounds called nitrules

# Nitrogen Essential to Plant Life

Although nitrogen is essential to the life of all cells, yet, with few exceptions, the cells of plants have no power to utilize the free nitrogen of the air It was long known that certain plants. such as clover, peas and beans, would thrive well on ground which would not produce good grain crops Also, it was known that the soil after growing these crops of clover, peas, and beans would become enriched, and would then produce a good crop of grain Years of investigation showed that these plants produced little nodules on their roots, and that in these nodules (Fig. 1) lived microorganisms which possessed the power of taking free nitrogen from the air and converting it into compounds of nitrogen for plant food These root nodule bacteria do not necessarily feed their captured nitrogen directly to their hosts, but excrete into the soil considerable quantities of the essential building blocks of the proteins, as aspartic acid which the host-plant is able to use Upon death the plant roots enrich the soil It is for this reason that crops are planted in rotation, i e, about every third year the ground is enriched by planting clover or some similar legu

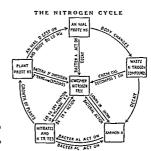


Fig 2—The N trogen Cycle The processes involving nitrogen in the I ves of plants and an mals never end hence the term nitrogen cycle

minous crop. Recent investigation has disclosed that higher plants can capture nitrogen directly from the air without the aid of root hacteria.

In addition to the nitrogen-fixing bacteria which change the nitrogen of the air into soluble nitrates, there are the denitrifying bacteria, which are constantly breaking down the nitrogen compounds in the soil. In this way large quantities of nitrogen are returned to the air as shown in Fig. 2.

# Uses of Nitrogen:

The nitrogen in the air serves to dilute and thereby diminish the chemical activity of the oxygen. Nitrogen enriches the soil through the agency of certain plants, from which the same or other plants build up complex compounds in their growth. Animals feed upon these plants, and assimilate the nitrogenous matter which then becomes an essential part of animal tissue. In both plants and animals the nitrogen is present chiefly in the form of proteins, which are complex compounds containing the elements carbon, hydrogen, oxygen, and nitrogen, and frequently phosphorus and sulfur. It should be remembered that the human body needs nitrogen, but cannot use the nitrogen of the air or any other form of nitrogen unless it be in the form of a protein molecule. The exact structure of the protein molecule is unknown. The simplest formula calculated for oxyhemoglobin, Crashushusobsecone, gives us some idea of the complexity of the protein molecule.

# Compounds of Nitrogen:

While a great many compounds of nitrogen are known it is sufficient to become acquainted with only a few of the simpler ones. Nitric acid (HNO<sub>3</sub>) has been discussed (p. 151).

summent to become sequamed with only a lew or he shalped ones. Nitro eacid (HNO<sub>3</sub>) has been discussed (p. 151).

Ammonia (NH<sub>3</sub>): Ammonia gas is produced whenever nitrogenous organic matter as blood, flesh, or manure decays. Originally it was prepared by simply heating the hoofs and horns of animals, and passing the evolved gas into water. Some ammonia is obtained by heating soft coal in the absence of air, a process called destructive distillation. The direct synthesis of ammonia from nitrogen and hydrogen by the Haber process is the most important commercial source. In the laboratory, ammonia is readily prepared by heating any ammonium salt with a strong base as shown in the following countion:

$$NH_4CI + N_0OH \rightarrow N_0CI + NH_4OH$$

$$\downarrow \downarrow$$

$$NH_3 + H_2OH$$

Ammonia is a colorless gas, having a characteristic irritating, and penetrating odor, and it is extremely soluble in water. When dis solved in water it is called aqua ammonia, ammonia water, or ammonium hydroxide, and in this form it has a household use as a cleaner and water softener.

Some soap is generally added to the household ammonia in order to assist in the cleaning Ammonia, liquefied under pressure is used in refrigeration plants to produce cooling by its own expansion Manufactured ice is made by this process as explained on page 162

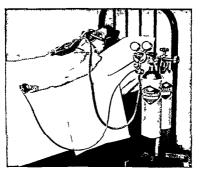


Fig 3—Analgesia Controlled by the Patient. By means of a specially constructed machine for the induction of nitrous oxide and axygen a patient between this usage into a state of analgesia. Releasing the pressure on the bulb automatically shuts off the nitrous oxide and at the same time increases the flow of axygen. Why is there no danger of complete unconsciousness? Courtery The Chia Chemical and Mfg Co.

SALTS OF AMMONIA Ammonia combines with any acid, and the compound formed is an ammonium salt, for example

#### NH<sub>3</sub> + HCl → NH<sub>4</sub>Cl

Ammonium chloride is the salt formed in the above reaction. All of the ammonium salts are very soluble and some find extensive use in medicine as heart stimulants and expectorants. Smelling salts are made by mixing unstable ammonium carbonate with some pleasant smelling extract.

Nitrous Oxide (N<sub>2</sub>O) Nitrous oxide is the practically odorless, hight gas which the dentist and physician use as an anesthetic for many operations (Fig 3). It was the first gas ever used to render a patient unconscious of pain. When inhaled in limited quantities, nitrous oxide produces a kind of hysteria and consequently has offen been referred to as "laughing gas." It is our weakest inhala tion anesthetic, but our safest one because oxygen is always the antidote, the color of the patient, the breathing and reflexes are guides showing the depth of anesthesia. When mixed with oxygen (8 to 10 per cent) as an anesthetic it is quick in action pleasant to take, evanescent in its effect, and because of its nontoxicity causes no permanent effect of any significance. Relaxation of the muscles with introus oxide is very slight, and consequently this anesthetic is not used where deep relaxation is required, as in major surgery

Amno Acids These are discussed more fully later (p 384), and it is, therefore, sufficient to know at this time that these acids are important compounds of nitrogen and are the end products of the digestion of protein. They are absorbed from the intestine, taken into the blood stream and carried to the tissues. Amino acids are the decomposition products of meats eggs and other proteins by enzymes or by bacterial action.

#### SELF-TESTING QUESTIONS

- 1 How would you define a metal and a nonmetal from their properties and also from the electron standpoint?
- 2 How does nitrogen occur in nature?
  3 What are the chemical properties of nitrogen?
- 4 How does nitrogen of the air enrich the soil?
- 5 How do we obtain the nitrogen that serves to build the tissues of the body?
- 6 What is the composition of the protein molecule?
- 7 How is ammonia produced?

- 8 What are some common names for NH4OH?
- 9 For what is ammonium hydroxide used?
- 10 What are the medicinal uses of ammonium salts?
- 11 Why is nitrous oxide considered a good anesthetic?12 How are amino acids formed and what does their presence indicate?

# II. HALOGENS, SULFUR, PHOSPHORUS

# The Halogens

The nonmetallic elements, chlorine (Cl), bromine (Br), iodine (I), and fluorine (F), make up a group of elements called the "halogens," i.e., salt formers. These elements have very similar properties, and all of them are poisonous and corrosive, and combine with hydrogen to form acids.

CHLORINE Thus is a greenish yellow gas with a disagreeable, suffocating odor, and a very irritating action on the mucous membranes of the nose and mouth Chlorine is very poisonous, and exposure to it for short periods produces serious pulmonary trouble. When chlorine is breathed it combines with the hydrogen of the water in the tissues and forms hydrochloric acid, which destroys the air cells in the lungs.

$$Cl_2 + H_2O \rightarrow HCl + HClO$$

$$\downarrow HCl + [O] (noscent oxygen)$$

Bleaching powder (CaOCl<sub>2</sub>), a compound prepared from slaked lime and chlorine, is used as a convenient source of chlorine for whitening paper and bleaching cotton and linen fabrics. As has been stated, liquid chlorine is extensively used in the disinfection of public water supplies (p. 78), and the treatment of seware

Even though chlorine has been widely used as an antiseptic, its irritating and poisonous properties have prevented its use in or on the himman body. Nevertheless, some morganic chlorine compounds (hypochlorites) as chlorinated lime, Javelle water, and Dakin's solution (p. 150), have been used. Owing to the instability of these morganic compounds, however, certain organic chlorine compounds (e. g., the chloramines) have been widely substituted. They keep better and liberate chlorine more slowly under favorable conditions Chlorine is used to form the hypnotic chloral (CCl<sub>2</sub> CH<sub>0</sub>), and the anesthetics chloroform (CHCl<sub>3</sub>) and ethyl chloride (C<sub>2</sub>H<sub>3</sub>Cl). Considerable chlorine in the form of carbon tetrachloride (CCl<sub>4</sub>), and trichloroethylene, is used in the drycleaning bus

ness. Carbon tetrachloride is used in making fire extinguishers of the Pyrene type

BROMINE. This is a dark red liquid which has a strong suffocating smell. It gives off irritating furnes and has an intense corrosive action on the skin, causing a very serious burn; consequently, great care should be used in handling this element. Bromine acts on the nose and throat as does chlorine, and also irritates the eyes. Sodium, potassium, and ammonium bromides are all used medically as sedatives, but their continued use disturbs digestion, and brings on the state of brominism Other sedatives are discussed on page 298.

IODINE This is a dark gray solid which easily vaporizes into violet-colored fumes. It is almost insoluble in water but very soluble



Fig 4—Hyperthyroidism and Hypothyroidism Overactivity and underactivity of the thyroid gland markedly influence the energy metabolism in which case will it be above normal? Courtery, University Haspitals, Cleveland

in alcohol which contains a small quantity of potassium iodide. This solution has very valuable antiseptic properties, and it is sold commercially as tincture of iodine. Because of its coagulating effect upon the tissues, and consequent inability to penetrate or irrigate deep wounds, its use is limited to disinfections of skin and surface wounds. Concentrated solutions and repeated applications of iodine are irritating and destructive to tissues. Many compounds of iodine are used in medicine. Recently, preparations called iodophors have been developed for a more effective use of iodine. In minute quantities, iodine is a constituent of most natural waters, and as a constituent of the active principle of the thyroid gland it is essential in maintaining the normal rate of metabolism. A deficiency of iodine in some instances, at least, brings on an enlargement of the thyroid gland known as simple goiter. Small amounts of sodium iodide in table salt have been successfully used where the gland is deficient in its secretion of iodine and has not become enlarged to any great extent. Where there is an overproduction of the active principle, as in exophthalmic goiter, the use of an iodide is to be avoided since it might bring on hyperthyroidism. Patients with goiter are also being treated with radioactive iodine (p. 234.)

When a very small amount of iodine solution is brought in contact with starch a blue color is produced. This characteristic reaction is used as a test for either iodine or starch.

FLUGRINE: This element is the most reactive of the nonmetals and certain salts find important industrial uses. Of interest is the use of fluorides for drinking water to prevent dental caries. Research has shown that a fluoride content from .5 to 1.2 parts per million is a desirable concentration for this purpose. However, higher concentrations of fluorides in water result in mottled enamel of teeth in children. At the present, many communities are practicing fluoridation of water.

#### Sulfur:

We are all familiar with the yellow appearance of the nonmetal, sulfur, and we have previously learned that it is moderately active burns in air, and unites readily with many other elements. It is used in the preparation of sulfur dioxide, sulfuric acid, carbon disulfide, metallic sulfides, and vulcanized rubber. Medicinally, it finds a use in the treatment of some parasitic skin diseases such as scabies.

# Phosphorus:

Phosphorus, like sulfur, exists in different forms called "allo tropic" forms. In the case of phosphorus, the two most common forms are known as white and red phosphorus. The white variety is very flammable, a violent poison, and quite soluble in carbon disulfide Red phosphorus is not so active chemically, is not poisonous, or soluble in carbon disulfide. The chief uses of phos phorus are in making matches, rat poison and hard alloys Phos phates are important in maintaining the fertility of the soil Com pounds of phosphorus exist in the bones, teeth, muscles, nerves. and brain tissues. In the blood, one form of phosphorus is asso. crated with the fat content. In the body, a deficiency of phosphates makes weak bone structure

#### SELE-TESTING OUESTIONS

- 13 What are the halogens?
- 14 Why is chloring poisonous?
- 15 For what is chloring used?
- 16 What compounds of chlorine have been used for antiseptic purposes? 17 Give a medicinal use of sodium potassium and ammonium bromides
- 18 What is tincture of jodine?
- 19 What is the importance of jodine in the thyroid gland?
- 20 What is the effect of too much or too little jodine in the thyroid glands?
- 21 Name a medicinal use of sulfur
- 22 How do the two forms of phosphorus differ in their properties? 23 How is phosphorus important in the body?

# III. CARRON AND ITS COMPOUNDS

Carbon and its compounds have been known and prized from re motest antiquity as they are so important in supplying man's greatest needs-food warmth, and clothing Large quantities of carbon are found in the free state in nature, coal, for example, is an impure form of carbon

# Natural Forms of Carbon:

COAL. Coal exists in several varieties which represent different stages in the decomposition of vegetable matter in the absence of air At one time in our earth's history, vegetation flourished to a remarkable extent This vegetation evidently became covered to a great depth with earth, where under enormous pressure and in the absence of air, it underwent a slow decomposition with the evolu tion of gases, and the formation of coal

The many varieties of coal found on the market may be roughly divided into two great classes, namely, hard or anthracite coal, and soft or bituminous coal Bituminous coal contains more volatile matter than the hard coal It burns with a sooty flame and evolves more gases (hydrocarbon) than hard coal Soft coal is commonly used as fuel, and in the manufacture of illuminating gas

Some forms of coal, such as cannel coal and lignite, contain even less uncombined carbon, while peat is a first stage in the formation

of coal from plants

GRAPHITE This is a crystalline form of carbon found in nature Most of the graphite is now made by heating coal in an electric furnace. Graphite is made up of soft, flat scales which present a good sliding surface, and for that reason it finds extensive use as a lubricant. Some graphite is used to make "lead" pencils, and crucibles It also serves as a paint for iron ware.

DIAMOND This is the third form of carbon to be found in nature. It is also crystalline and is colorless when pure The different colors in diamonds are due to the foreign substances dissolved in the carbon. The diamond is the hardest substance found in nature and consequently has a use in making many cutting instruments. The real value of the diamond lies in its high index of refraction (ability to bend rays of light), which produces a sparkling play of colors. A diamond as found very seldom weighs more than 20 Gm. The largest diamond found weighed 3025% carats (a carat is about 0.2 Gm.), but subsequent cuttings reduced the largest single portion of this diamond to 516½ carats.

Amorphous Carbon This is a noncrystalline form and is a result of the decomposition of vegetable and animal matter in the presence of heat and in the absence of air The common physical properties of carbon, as the color and the specific gravity, are the results of the temperature at which the carbon is formed The blackest form of carbon is made at the lowest temperature.

LAMP BLACK AND CARBON BLACK Lamp black is practically pure carbon and is produced by the incomplete combustion of hydrogen and carbon, such as heavy oil. The operation is very analogous to the smoking of a coal oil lamp. The hydrogen of the hydrocarbons burns, but much of the carbon is left unburnt as a soft, greasy powder. Lamp black is used to make paint, and India and printer's ink. Carbon black is made by the same method from natural gas. It is the blackest and most

finely divided substance known to commerce, and is used in the rubber industry to improve the durability of rubber products

BONE BLACK This is obtained by heating bones in the absence of air It is used in the sugar industry to remove the yellow coloning matter from sugar solutions. Bone black is also used to adsorb the color in certain oils. It contains considerable calcium phosphate

CHARCOAL This is made by heating wood without access to air. The volatile matter expelled consists of such valuable substances as wood alcohol, acetic acid, and acetione. The operation is known as destructive distillation. The charcoal left is used as a fuel. On account of their remarkable power to adsorb gases, charcoal tablets are used as a gastric medicine. Gas masks used in warfare, and now in many industries as a protection against poison ous gases, contain a specially made charcoal known as activated charcoal. Activated charcoal also finds an important use in the purification of industrial waters (p. 79). One volume of such charcoal is able to adsorb several hundred volumes of some gases.

CORE This is a harder form of carbon, and is prepared at high temperatures by the destructive distillation of soft coal. The volatile materials here are coal gas, ammonia, carbohe acid, ben zene, and tar. Coke is a very valuable fuel.

#### Chemical Properties:

In its combined form, carbon exists in thousands of compounds Natural gas, petroleum, carbonates, and all living organisms are largely composed of compounds of carbon

The forms of carbon differ in their physical and to some extent in their chemical properties however, all forms are odorless, taste less solids, insoluble in water. At ordinary temperatures carbon is inactive, but at high temperatures it is very active and combines directly with oxygen to form either carbon dioxide (CO<sub>2</sub>) or carbon monoxide (CO). Carbon also combines with a few elements to form compounds called carbides, e.g.,

$$SiO_2 + 3C \rightarrow SiC + 2CO$$
Solition carbide justed as an obrasive  $CaO + 3C \rightarrow CaC_2 + CO$ 

The calcium carbide is used in making acetylene gas  $C_0C_2 + 2 H_2O \rightarrow C_2H_2 + C_0(OH)_2$ 

Carbon also unites with sulfur to make carbon disulfide, a good solvent.

 $C + 25 \rightarrow CS_2$ 

## SELF-TESTING QUESTIONS

24. What is a hydrocarbon?

25. How does anthracite coal differ from bituminous coal?

26. What is graphite and for what is it used?

- 27. What are two crystalline forms of carbon?
- 28. How are the amorphous forms of carbon produced?

29. For what is each amorphous form used?

- 30. With what will carbon unite?
- 31. Name two important carbides and their chief use.
- 32. What is destructive distillation?

#### IV. OXIDES OF CARBON

# Carbon Dioxide (CO<sub>2</sub>):

This is a colorless gas that is always formed when carbon fuels burn completely.

 $C + O_2 \rightarrow CO_2$ 

Carbon dioxide is also formed in respiration, and during the fermentation of sugar to make alcohol. Carbon dioxide is given off from volcanoes and is found in coal mines under the name of choke



Fig. 5—Pertussis Outfit. Inhalations of carbon dioxide-oxygen keep lungs sufficiently clear so that the paroxysms may be appreciably diminished in frequency and intensity. It is especially useful in cases of whooping cough. How does this mixture of gases promote recovery? Courtesy, Ohio Chemical and Mfg, Co., Cleveland, Ohio.

damp. Since it reacts with limewater to make a white precipitate, this property constitutes a simple test for carbon dioxide

In respiration, any increased exertion causes a correspondingly increased amount of carbon dioxide to be given off by the tissues and absorbed by the blood Since carbon dioxide readily unites with water, forming carbonic acid, the hydrogen ion concentration in the blood is increased.

H<sub>2</sub>O + CO<sub>2</sub> ⇒ H<sub>2</sub>CO<sub>3</sub> ⇒ H<sup>+</sup> + HCO<sub>3</sub>-

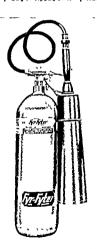


Fig. 6—A CO<sub>2</sub> Fire Exhinguisher. The cylinder is charged with carbon dioxide under pressure. What are advantages of this type of exhinguisher? Courtesy of Fyr Fyler Company.

This resultant increased acidity in the blood stimulates the nervous centers of respiration to an increased activity. The respiration is increased in order to expel the carbon dioxide from the blood, thereby lowering the hydrogen ion concentration. Consequently more rapid breathing after exertion is not wholly due to a need for more oxygen.

In the chapter on oxygen we learned that pure oxygen is often administered in cases of suffocation or collapse. Experiments have shown that a mixture of 93 per cent oxygen with 7 per cent carbon dioxide is much better to administer than pure oxygen, since this mixture promotes deeper breathing. Deep breathing enables the patient to expel more quickly a poisonous gas, such as carbon monoxide, and enhances the possibilities for recovery. For prevention of postoperative complications, a common practice is to give the oxygen carbon dioxide mixture by inhalation for three minutes every hour for 24 hours, to patients who have had major operations with prolonged anesthesia

Carbon dioxide is a food for plants, and it is used in the manufacture of soda water and similar beverages It is a good fire extinguisher, since it is a heavy gas and a nonsupporter of combustion (Fig. 6). It also serves as an aerating agent in baking since it produces the desired lightness. In the solid form, under the name of "Dry Ice," carbon dioxide is used as a commercial refingerant.

# Carbon Dioxide-Oxygen Cycle:

Carbon is a necessary element for both plant and animal structure Animals obtain carbon through the agency of the plants, while the plants, in turn, obtain it from the carbon dioxide of the air

In the presence of sunlight and the catalytic agent, chlorophyll, the plant takes the carbon dioxide from the air, combines it with the water from the ground, and stores it up in the plant as a carbo hydrate with the absorption of solar energy This chemical process is called photosynthesis.

According to theory there a first formed carbonuc and then formaldehyde which latter substance combines with several of its molecules (polymenzuse) to form glucose. This process continues with the elimination of water and produces polysaccharides (starch and cellulose) The equations are as follows.

 $H_2O + CO_2 \rightarrow H_2CO_3$  6H CHO  $\rightarrow C_6H_{12}O_6$  $H_2CO_3 \rightarrow H$  CHO  $+ O_2$   $XC_6H_{12}O_6 \rightarrow (C_6H_{10}O_5)x + XH_2O$ 

6 CO<sub>2</sub> + 6 H<sub>2</sub>O 
$$\xrightarrow{\text{sunlight}}$$
 C<sub>6</sub>H<sub>12</sub>O<sub>6</sub> + 6 O<sub>2</sub>

From From thorophyl Energy being stored

Notice that solar energy (677 2 Cal) is required to produce a gram molecule of a simple carbohydrate (180 Gm) Upon being used as a food, oxidation releases the potential energy (calories stored therein) with a reversal of the above chemical reaction

This, then, shows the interdependence of plants and animals for both carbon dioxide and oxygen (Fig. 7). No other chemical reac-



Fig. 7-Carbon Dioxide-Oxygen Cycle

tion in all the world is of such great importance to man since through photosynthesis the carbohydrates produced not only supply us with food but they are also used by the plant in the manufacture of fats and proteins. Furthermore, only in this manner do we get enercy directly or indirectly from plant and animal life

# Carbon Monoxide (CO)

This is always formed when carbon burns in a limited supply of oxygen

The gas burns with a pale blue flame and may be observed by watching the flame over any coal fire. Its most striking chemical property is its ability to combine with oxygen. Carbon monoxide is extremely poisonous, causing more deaths than all other gases Just as long as fire is used for heat and power, the hazards of carbon monoxide can never be entirely eliminated. Air containing 01 per cent of carbon monoxide gas will produce insensibility in two hours and death shortly thereafter. Carbon monoxide is often formed in mine explosions, and birds have been used to warn the men of the

presence of this gas. Birds breathe a larger volume of air for their weight than does man (higher rate of metabolism) and hence are more quickly overcome.

Today it is a practice to use instruments (meters) to detect and record concentrations of carbon monoxide in the air.

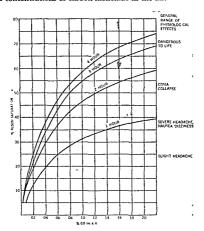


Fig. 8.—Effects of Carbon Monoxide on Human Beings Courtesy, Mine Safety Appliances Company

When carbon monoxide is breathed it combines with the red corpuscles of the blood to form carbon monoxide hemoglobin (carbonyl hemoglobin), and renders these corpuscles incapable of taking up oxygen, thus producing carbon monoxide intoxication. This, of course, results in suffocation, death being due to paralysis of the respiratory system. In ordinary suffocation the blood is blue, but in the case of carbon monoxide poisoning, the blood is a bright red, almost like arterial blood. Since incomplete combustion always produces carbon monoxide, great care should be exercised wherever combustion is taking place. The danger is great wherever automobile engines are running in enclosed buildings. Also since all cars average about 5 per cent of carbon monoxide in their exhaust, it is evident that this alone constitutes a great health hazard (Fig. 9). The last statement



Fig 9.—Exhaust Fumes Contain a Poison. With the motor running, the air in a closed garage soon becomes fatal, because of the accumulation of poisonous carbon monoxide gas. What makes this gas so dangerous?

means that many automobiles produce approximately one cubic foot of carbon monoxide per minute, which by accumulation in a closed one-car garage is sufficient to produce paralysis in 10 or 15 minutes and death within half an hour. When asphyxia does occur it is the result of the failure of respiration. At such times, the poisonous carbon monoxide must be removed, the respiratory stimulant carbon dioxide lost during the development of asphyxia must be restored, and the oxygen-carrying power of the blood must be renewed. Methylene blue (I per cent) has been claimed as an antidote for carbon monoxide as well as for cyanide poisoning.

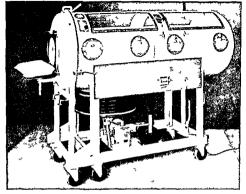


Fig 10-Drinker Collins Respirator Courtesy Warren E Collins Inc.

Whether hypodermically injected methylene blue can promote recovery is to be questioned, but it is well established that recovery may be brought about by the inhalation of oxygen which changes the carbon monoxide hemoglobin back to oxyhemoglobin and at the same time saturates the blood with oxygen

In this "machine age" the machine shown in Fig 10 produces artificial respiration when in certain cases normal respiration ceases

Gas masks used for adsorbing carbon monoxide contain a mixture of metallic oxides, mostly MnO<sub>2</sub>, called "Hopcalite," which acts as catalyzer to make the carbon monoxide combine with the oxygen of the air to form carbon dioxide.

#### SELF-TESTING QUESTIONS

- 33 In what ways is carbon dioxide formed?
- 34 What is choke damp?
- 35 What is a test for carbon dioxide?
- 36 How does carbon dioxide aid in anesthesia?

- 37 What are some commercial uses of carbon dioxide?
- 38 What is photosynthesis?
- 39 How do plants and animals regulate the amount of oxygen and carbon dioxide in the air?
- 40 How is carbon monoxide produced?
- 41 What is the most important chemical property of carbon monoxide?
- 42 What is the effect of breathing carbon monoxide?
- 43 How may the presence of carbon monoxide be detected?
- 44 What is the immediate treatment for asphyxia when it is caused by carbon monoxide?

#### V. METAIS

## Classifying Elements as Metals:

So far we have dealt almost exclusively with the nonmetallic elements, such as oxygen, nitrogen, the halogens, sulfur, phosphorus, and carbon Each of these elements (C excepted) with more than half of the electrons needed to fill out its outer atomic shell usually gains electrons, and consequently has a negative



Fig. 11—Nonmetal Oxygen (O) Six electrons in outer shell. Easily gains two electrons. Negative valence of 2.0



Fig 12—Metal Sod um (Na) Ore electron in outer shell Easily loses are electron Positive volence of 1, Na+

valence The oxygen diagram shows the valence electrons of a typical nonmetal (Fig 11)

On the other hand, there are over fifty elements each of which has less than half of the electrons needed to fill out its outer atomic shell of eight. They give up their electrons easily during chemical change, to form positive ions. These elements are called metals nage, to form positive ions. These elements are called metals eneral they units with nonmetals to form salts, they decompose acids, and they units with oxygen to form basic anhydrides, i.e., their hydroxides are bases. The diagram above is that of sodium, a typical metal (Fig. 21).

# Listing Metals According to Their Activity:

The chemical activity of metals depends upon the ease of their atoms to ionize, and since this ability varies it is possible to arrange the metals in the order of decreasing activity. This partial series of metals, with the inclusion of hydrogen, is referred to as the Activity or Displacement Series (p. 145) because of the ability of each element to replace the metals below from their salts. Thus an iron nail will replace copper in a copper sulfate solution.

Fe
$$^{\circ}$$
 + Cu $^{++}$ SO<sub>4</sub> $^{-}$   $\rightarrow$  Fe $^{++}$ SO<sub>4</sub> $^{-}$  + Cu $^{\circ}$   $\sim$  2  $\leftarrow$   $^{-}$ 

A glance at the Activity Series shows the feasibility of using aluminum vessels to hold solutions of those salts above it, of using chromium or nickel plated instruments to handle common salt (NaCl) and Epsom salt (MgSO<sub>4</sub>) dressings or packs, and of using vessels made of aluminum, zinc, or iron when cooking foods containing salts of those metals above them. On the other hand, avoidance or caution must be exercised in using solutions of salts of those metals below the above mentioned metals. For instance,

aluminum vessels should not be used to hold iron solutions, chromium or nickel plated instruments should not be left in contact for any appreciable time with bichloride of mercury (HgCl<sub>2</sub>) or silver mirate solutions, and lastly similar precautions must be kept in mind when cooking foods which contain iron, such as spinach, in aluminum vessels

The position of hydrogen is noteworthy All metals above it are very active, especially those at the top, and at some tem peratures can replace hydrogen in water, acids, and many other compounds con taming hydrogen. On the other hand, those metals below hydrogen are not so active, do not liberate molecular hydrogen from acids, can be acted upon only by oxidizing acids (HNO2, HSO4), may occur uncombined in nature are easily extracted from their ores, and ordinarily do not corrole. It is the lack of chemical

ACTIVITY SERIES

Potassium Calcium

Sodium

Magnesium

Aluminum

Zinc

Chromium

Iron

Cobalt Nuckel

Tın

Hydrogen

Copper Mercury

Silver

Platinum Gold activity or the resistance to corrosion (oxidation) that makes certain metals desirable in the home, hospital, and in industry Articles made from them make a good appearance and preserve their usefulness over a long period of time. In estimating the usefulness, we must not fail also to consider their physical properties luster, as the shining qualities of silver, malleability, or the ability to be hammered out into thin sheets, as gold leaf, ductility, or the ability to be drawn out into wire, as platinum, hardness, or the resistance to permanent change of form, as chromium, conductivity of heat, as aluminum, and the conductivity of electricity, as copper. The physical properties of the familiar metals as well as their resistance to wear and corrosion determine their usefulness.

# Tarnishing of Metals

Most metals become discolored or tarmshed, either after being used or exposed to moist air. In the latter case, the tarmsh generally is due to the formation of an insoluble oxide, such as that formed on iron, lead, aluminum, zinc, and nickel. Sometimes the tarmsh is due to the action of oxygen, carbon dioxide, and moist are as the formation of a carbonate upon copper, or alloys containing copper (brass, bronze). At ordinary temperature, tin and silver do not become coated with a noticeable tarmsh, but silver in the presence of sulfur or sulfur compounds, as hydrogen sulfide in the air or the sulfur in egg yolk and other foods containing sulfur compounds, darkens because of the formation of black, insoluble silver sulfide. The tarmsh or rust on iron is generally considered as the hydrated form of iron oxide (2 FeoQ. 3 H<sub>2</sub>O)

In addition to the tarnish consisting of oxides, carbonates, and sulfides, it is also well to consider the presence of grease, especially in the case of kitchen utensils.

### General Methods of Removing Tarnish

Both acids and alkalies remove grease and some types of tarnish, but they cannot be used on all metals Grases is readily dissolved from metals by naphtha or gasoline without any injury to the metals. Tarnish may be removed conveniently by scouring with abrasive material, care being taken not to use any abrasive that will scratch the metal. These abrasives include infusorial earth (siliceous earth) for scouring soaps and powders, whiting (chalk) for polishing silverware, and steel wool with good soap suds for kitchen utensils (except those of tim).

## Cleaning of Some Common Metals

Cleaning in the hospital is a most important factor since it includes the proper maintenance of cooking utensils, surgical instruments, furniture and other metallic materials. Methods for clean ing and polishing of some common metals follow

ALUMINUM This is the most interesting metal used in the home It is characterized by being very light in weight and having a silvery white color, the dullness usually associated with aluminum articles is the result of a thin coating of the oxide, which prevents any further tarnishing of the metal. This oxide tarnish may be removed by cooking an acid food in the aluminum vessel, or by allowing vinegar to stand for several hours in the vessel. Since aluminum dissolves and darkens in contact with alkaline solutions, washing soda or strong alkalies cannot be used for cleaning aluminum ware.

#### 2 Al + 6 NaOH → Nas AlOs + 3 Ha

Because aluminum is durable, attractive in appearance, light in weight, easy to clean, an excellent conductor of heat, almost un changed in air or water at ordinary temperature, and not affected by common foods, this metal is extensively used in making many kitchen utensils

Before leaving the subject of aluminum it might be well to call attention to the compound sodium aluminum sulfate (alum), which is used in making certain brands of baking powder. This compound (NaAl(SO<sub>4</sub>)<sub>2</sub> 12H<sub>2</sub>O) hydrolyzes in water to form an acid which reacts with the sodium bicarbonate present to liberate carbon dioxide. The so called combination baking powders usually contain this compound and mono calcium phosphate as the acid forming ingredients which react with the baking soda to liberate carbon dioxide. All baking powders are a mixture of sodium bicarbonate (baking soda) and a solid acid or acid salt (Ca(H<sub>2</sub>PO<sub>4</sub>)<sub>2</sub>, NaH<sub>2</sub>PO<sub>4</sub>, KHCJH<sub>4</sub>O<sub>6</sub>)

IRON Upon oxidation in moist air, iron forms scales of rust (2 Fe<sub>2</sub>O<sub>3</sub> 3 H<sub>2</sub>O), which peel off and expose a new surface for further corrosion. The amount of iron lost yearly in this way is enormous, the estimation being over 15 per cent of that produced. To protect iron from rust and corrosion it is covered with some resistant substance as paint, or enamel (glass glaze), the latter substance is widely used in making cooking utensils. Iron and enamel may be cleaned with abrasives containing alkalies.

Most of the iron used today is an alloy of iron called steel, which contains varying amounts of carbon up to 0 2 per cent and traces of other elements, the amount used depending upon the intended use of the steel. Of the many steel alloys the most interesting are those first introduced as stainless kitchen utensils, but which are now used in the manufacture of stoves, plumbing fixtures, refirgerators and even in the surfacing of buildings (Empire State, New York City) for protection against corrosion. Such steels contain chromium and a small amount of nickel or cobalt.

Iron also may be protected from rust or corrosion by coating it with more resistant metals, the most important of which are tin, nickel, chromium, zinc, silver, and gold

Tin This is extensively used to cover iron and make the familiar tin cans in which foods are preserved. Some tinware is still used to make kitchen utensits. The metal is very resistant to the formation of tarmish, and to the action of food acids or weak alkalies. Tinware can be cleaned and polished with soft abrasives containing weak alkalies (weahling soda).

NICKEL This is often used to plate steel articles because of its hardness and ability to take a high polish which slowly diminishes in moist air. It is for this latter reason that dimmum is largely replacing nickel plating. Both of these metals may be cleaned and polished by the same abrasives used on tin.

Silver This is a soft metal capable of a high polish. Its tarnish usually is due to the formation of black silver sulfide which may be removed by a soft abrasive containing ammona water. The tarnish may be removed more easily by placing the silverware in contact with aluminum in a vessel containing a warm solution of washing soda and salt. Since aluminum vessels become stained it is better to use an enamel pan containing a piece of aluminum.

Zinc Coating iron with zinc protects the iron from corrosion because the thin layer of zinc oxide or carbonate formed on exposure to air sticks and prevents any further action. Iron coated with zinc is called galvanized iron, a very familiar product in buckets, garbage cans, wire, and similar articles. Cleaning is accomplished by the use of ordinary abrasives and soap

Goth This metal is not acted upon by air, moisture, or the common acids However, in alloying it with copper to increase its hardness, the gold in common use tends to become tarmshed. A very soft abrasive, preferably one containing ammonium hydroxide, cleans and noishes soid stricles.

In medicine a colloid prepared from gold chloride is used to aid in diagnostic tests on cerebrospinal fluid. Normal fluid in serial dilution does not alter the shade of the beautiful salmon color of colloidal gold when it is mixed with it. Spinal fluid from patients with meningitis, poliomyelitis and various stages of syphilis, etc gives definite color changes ranging from the original salmon to purples and colorless in dilutions of a series of spinal fluid concentrations—a gold curve

#### SELE-TESTING QUESTIONS

- 45 What is a metal?
- 46 What is noteworthy concerning the position of hydrogen in the replace ment series?
- 47 What does the usefulness of the common metals depend upon?
- 48 What is the nature of tarnish?
- 49 How in general may tarnish and grease be removed from metals?
- 50 What precautions must be used in cleaning aluminum?
- 51 What is the composition and what are the uses of stainless steels?
- 52 Why is chromium plating replacing nickel plating?
- 53 How may silverware be easily cleaned?
- 54 What is galvanized iron?

# VI ALLOYS OF METALS

# Nature of Alloys.

In using the term metal, we usually think of pure metallic elements, as copper and aluminum. A study, however, of the famil airly used metals shows the very surprising fact that the great majority of them are composed of two or more pure metals melted together into what is called an alloy. The art of making alloys is very old, and was practiced during an early period of human progress (Bronze Age). The variations in their composition and resulting properties indicate that alloys are not always mixtures or true solutions of elements, but may consist of solutions of definitely formed compounds, or all of these together.

## Properties of Alloys:

The properties of alloys are quite different from those of the original metal constituents. As a general rule, alloys, as compared to their constituents, have low melting points, such as the fusible alloys for automatic sprinklers, they have different colors as green and white gold, less electrical conductivity as the resistance wire nelectrical toasters, greater resistance to corrosion as stainless

#### SOME COMMON ALLOYS

Name	Composition	Properties (Distinctive)	Uses
Brasa	Cu 60 80 Zn 20-40	Resista corrosion	Castings
Bronze	Cu 70 95 Sn 1 18	Hard noncorroding	Ornaments statues
Monel Metal	Cu 27 Ni 68 Mn & Fe 5	Resusts corresion	Amd resisting cor
Aluminum Bronze	Al 2 10 Cu 90-98	Hard gold or silver	Ornaments imits
Duralium	A1 95 Cu 3 Mn 1 Mg 0 5	Light noncorresive	Aircraft parts
Magnalium	Al 90 94 Mg 2 10	Light noncorrosive	Castines aircraft
Gold Com	Au 90 Cu 10	Yellow color perma	Coma jewelry
Green Gold	Au 60 Ag 35 Cu 5	Beauty	Jawelry
Gray Gold	Au 20 Pd 80	Beauty	Jewelry
White Gold	Au 15 Pd 85	Beauty	Jewelry
Silver Com	Ag 90 Cu 10	Beauty permanence	Com jewelry
Sterling Silver	Ag 92 5 Cu 7 5	Beauty permanence	Jewelry
Duriron	Fe 85-88 St 12 15	Resists corrosion	Acid containers
Stainless Steel	Fe 74 Cr 18 Ni or Co 8	Noncorrosive	Kitchen utensils
Nickel Coin	N <sub>1</sub> 25 Cu 75	Beauty noncorrosive	Couns
Solder	Sn 75 Pb 25	Melts at low temper ature and sticks	Soldering
Wood s Metal	B <sub>1</sub> 50 Pb25 Sn12 5 Cd 12 5	Low melting point	Safety fuses
Pewter	Sn 85 Sb 15	Soft	Tableware utensils
	_	1	

steel, and they are harder, as is the chromium nickel steel used in making armor plate

There are many thousands of alloys, of which the most important is steel. The previous table lists some common alloys, their composition, properties, and uses

#### SELF-TESTING QUESTIONS

- 55 What is an alloy? 58 What may determine the properties of alloys?
- 57 What are five general properties of alloys?
- 58 What is the most important alloy?

### SUGGESTED ACTIVITIES

- I THOUGHT PROVOKING QUESTIONS
  - 1 What properties of ammonia make it suitable for use in the prepa ration of manufactured ice?
  - 2 State briefly the physical and chemical ways in which the halogens resemble each other
  - 3 Explain how Dakin's solution is used, and what chemical action takes place in using the solution
  - 4 What substances already studied are used as bleaching agents? What chemical properties do they possess in common?

- 5 Name five elements that exist in allotropic forms
- 6 Explain how chlorine is used in the disinfection of water supplies
- 7 Explain how the burning of sulfur serves to disinfect a room
  8 Name a medicinal use of a specific ammonium salt, nitrate, chloride.
- bromide, iodide, sulfate, phosphate, and carbonate

  What are the properties of chlorine that made it suitable for gas
- 9 What are the properties of chlorine that made it suitable for gowarfare?
- 10 What might be the hazard of congested motor traffic in a tunnel?
- 11 The cost of solid carbon dioxide is approximately 25 times the cost of ordinary ice. How do you account for its use?
- 12 CO<sub>2</sub> is a respiratory stimulant, however, too much CO<sub>2</sub> rebreathing has what disadvantage? What does the rebreathing of CO<sub>2</sub> interfere with?
- 13 How may carbon monoxide find its way into the home?
- 14 Why not prepare nitrogen by burning a candle in the air?
- 15 Give the name and formula for a compound of mtrogen in which nitrogen has a valence of 3, of 5
- 16 Explain why dry ammonia does not affect litmus paper
- 17 Why may ammonium salts be used as smelling salts?
- 18 What variety of phosphorus is used in the manufacture of safety matches? In the manufacture of rat poison?
  - 19 Name an element acting as a metal in a definite compound, and as a nonmetal in another compound
- 20 Zinc is higher than iron in the replacement series Why is it used for coating iron?

choke damp

- 21 Write the reactions between alum and baking soda
- II VOCABULARY TESTING OF NEW TERMS

nitrifying bacteria halogen
nitrogen cycle allotropic

ntrogen cycle allotropic photosynthesis amphoteric amorphous alloys metal destructive distillation nitride

nonmetal carbide fluoridation

- III TOPICS FOR ORAL OR WRITTEN REPORTS
  - 1 Composition of Inspired and Expired Air
    - 2 Invention and Development of Matches
    - 3 The Fixation of Nitrogen
    - 4 Medicinal Applications of the Halogens
    - 5 The Status of Water Fluoridation in My Community 6 Dangers of Carbon Monoxide Poisoning
    - 6 Dangers of Carbon Monoxide Poisoning

TO THE INSTRUCTOR The laboratory time may well be used this week for either oral or written work, making a general survey of the fundamentals of the inorganic chemistry taught

### LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on pages 693, 695, 696, 698, 700

# X RAYS, RADIOACTIVITY, AND NUCLEAR CHEMISTRY

#### CHAPTER OUTLINE

- T X RAYS
  - (a) Discovery and nature of x rays (b) Use of x rava
- II RADIUM AND RADIOACTIVITY (a) Discovery and properties of
  - radium
  - (b) Nature of radioactivity (c) Uses of raduum
- III NUCLEAR REACTIONS (a) Nature of nuclear reactions

- IV ADDITIONAL RADIOACTIVITY
  - (a) Production of radioisotopes
  - (b) Radioisotopes in medicine and nutration
  - NUCLOUS ENERGY (a) Source and magnitude of
    - nuclear energy (b) Splitting the uranium nucleus

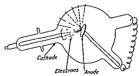
    - (c) Plutonium (d) Hydrogen bomb (e) Physiological effects

### I. X RAYS

### Discovery and Nature of X rays:

Roentgen in the year 1895 observed that the passage of an electrical discharge through a highly evacuated Crookes' tube produced an unusual type of radiation. This type of radiation, now known as the x ray, is generated when rapidly moving electrons strike a massive target. The essentials of an x-ray tube are shown





in Fig. 1. When such an evacuated tube is operated under a high voltage, electrons stream across the tube from the concave cathode and bombard the anticathode or target. The impact of the electrons (cathode ray) on atoms of the target gives rise to the x radiation. Such rays are in many respects similar to ordinary light rays. The fundamental point of difference is in the fact that x rays have much shorter wave lengths

### Use of X rays:

X rays are in themselves invisible, yet they cause many substances to fluoresce or to glow and become luminous By reason

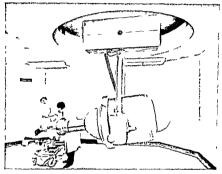


Fig 2—X ray Therapy Treatment View of a 1,000,000 volt x ray unit being positioned for treatment What factors determine the length of time for a treatment? Courtest, General Electric Company

of their very short wave lengths, x rays are able to pass through many substances, for example flesh, which are opaque to ordinary light. More dense objects such as bones and metals largely stop the radiation and in this way produce shadows. This makes it possible to prepare x-ray photographs (roentgenograms) which are of considerable aid to the physician. A bone fracture can be studied, or a piece of metal, such as a bullet, can be located in the flesh. Bartium sulfate is opaque to x rays and when a water suspension of this salt is administered by mouth or rectum it coats the inner

surfaces of the stomach and intestinal tract, this makes it possible to secure x ray photographs of these organs

More recently x ray tubes have been developed to operate under very high potentials, frequently greater than 1,000,000 volts X rays generated in such tubes are referred to as "hard" rays, and are highly penetrative. In fact they resemble the gamma radiation which is emitted by radium and other radioactive elements during their process of decay. Short wave length x rays are in many instances replacing the gamma rays for the treatment of skin disorders, cancer, and other types of pathological tissue

#### II. RADIUM AND RADIOACTIVITY

## Discovery and Properties of Radium:

Within a year after the discovery of x rays the scientist Henri Becquerel found by accident that compounds of uranium undergradion as spontaneous disintegration in the course of which radiations are emitted. In one of his experiments Becquerel placed a piece of a compound of uranium on a photographic plate which was wrapped light tight in black paper. When the plate was developed, it was evident that the uranium compound was giving off a type of radia tion which, like the x ray, affected the photographic plate. Thus the specimen of uranium compound had taken its own picture.

At Becquerel's suggestion the French physicists Pierre and Marie Curie undertook the task of investigating further the source of this radiation. After months of intensive research they were able to announce the discovery of two new elements, namely polonium and radium. Radium was discovered in 1898 in the form of a compound, it was not until 1910, however, that Madame Curie's succeeded in isolating the metallic element itself. Radium was so named because of its radiations (giver of rays) and polonium was named after Poland Madame Curie's native country. Radium occurs in minute quantities in all uranium ores (carnotite, pitch blende) hence tons of raw material must be worked over and carried through long processes of concentration by successive fractional crystallizations, to isolate a few grams of a radium compound At the present time ores from the Belgan Congo and from the Great Bear Lake region in Canada are the main sources of radium

Madame Curie died at the sge of 67 of splastic permicious anemia brought on by a long accumulation of radiations. Pierre Curie was killed in a Paris street accident in 1906.

The amount of this element which has been produced to date in the form of its salts such as the insoluble sulfate, is estimated as nearly 1,000 grams, priced at about \$25,000 per gram

Investigators found radium to have strange properties. It gave off energy continuously in the form of radiations and heat, affected the photographic plate, glowed in the dark, ionized the air around it, caused zinc sulfade and many minerals to exhibit fluorescence and most noteworthy of all, killed bacteria and burned animal tissue placed near by This property of natural, spontaneous dis integration, exhibited by radium and a number of other elements, is termed natural radioactivity. Neither chemical combination nor physical treatment affects the radioactivity of such elements.

# Nature of Radioactivity

A thorough study by Rutherford and others has shown that radium and other naturally radioactive elements emit three types of rays namely the alpha beta, and gamma radiations The alpha

RAYS FROM RADIOACTIVE ELEMENTS

Radiation	Absorbed by	Relatue penetration	Velocity
Alpha (a)	Writing paper or	1	10 000-20 000 miles per
Positive charge	6 cm of air		second
Beta (β)	1 mm of lead or	100	About 100 000 miles per
Negative charge	equivalent		second
Gamma (7) No charge	13 cm of lead	10000	186 000 miles per second (speed of light)

radiation consists of a stream of particles which are helium nuclei. The nucleus of the helium atom is made up of two protons and two neutrons fience such particles carry positive charges and consequently are deflected when passed between oppositely charged plates or the poles of a magnet. The beta radiation is made up of particles which prove to be electrons identical with the electrons of the cathode ray in the x ray tube. Such particles are of negative charge and therefore when the beta radiation passes between the

poles of a magnet it is deflected in a direction opposite to that of the alpha radiation

The gamma rays are similar to light rays, but have a much shorter wave length Gamma rays resemble hard x rays. This radiation is not deflected in a magnetic field which is proof that it carries no charge. Gamma rays have a high power of penetration Light, radio communication rays, x rays, and gamma rays are all electromagnetic disturbances of different wave lengths.

gamma //ajpha

Fig 3—Radium Rays The gamma rays have the greatest speed. The alpha and beta rays are bent in opposite d rections in the presence of a magnet What does this prove about gamma rays? Courtesy Dynamic Chemistry. Rand McNally

The reader must not conclude that the radioactive elements disintegrate completely into the radiations just described When the nuclei of radioactive atoms lose alpha and beta particles, new elements result. The immediate successor of radium is an element named radon or radium emanation. Radon is a member of Group O of the periodic classification and, like helium and other members of this group, radon is a chemically inert gas. Nevertheless, thus element is in itself highly radioactive and emits penetrating gamma ravs.

During radioactive disintegrations, enormous quantities of heat are liberated. In the case of radium, one gram gives off 137 calories per hour. Thus heat is generated by collisions of alpha and beta particles with surrounding molecules.

Rutherford and Soddy have advanced the theory that radium is one member of a series of radioactive elements which begins with uranium I and terminates in an inactive isotope of lead. In addition to this series there are two others. One of these, the actinium series, is likely a branch of the uranium I series. The third series begins with thorium and, like the others, ends with an isotope of lead. The uranium series is presented in the table which follows.

THE URANIUM DISINTEGRATION SERIES

Element	Atomic Weight	Atomic Number	Radiation Emitted	Half life Period
Uranium I	238	92	α	4 67 x 10° yes
Uranium X i	234	90	β	24 5 days
Uranum X2	234	91	β	1 14 minutes
Uranum II	234	92	α	2 x 105 yrs
Ionum	230	90	α	76 x 104 yrs
Radium	226	88	α	1590 yrs
Radon	222	86	α	3 85 days
Radjum A	218	84 1	α	3 05 minutes
Radium B	214	82	β	26 8 minutes
Radium C	214	83	αβ	19 7 minutes
99 97% / \ 0 03%		1		
Radium C	214	84	at	1 x 10 6 sec
Radium C	210	81	β	1 32 minutes
Radium D (radiolead)	210	82	β	22 years
Radnum E	210	83 [	β	50 days
Radium F (polonium)	210	84	α	140 days
Radium G (lead)	206	82		atable

Loss of an alpha particle (nucleus of a beluum atom) decreases the atomic weight by four units and lowers the atomic number by two units Loss of a beta particle (electron) has no appreciable effect on the atomic weight, but increases the atomic number by more. The gamma radiation which accompanies loss of alpha and beta particles causes no change in either atomic weight or atomic number. A number of the elements listed in the series are in reality isotopes. For example, radium B, and lead all have the same atomic number of \$22, and hence are isotopes of lead. It is to be recalled that all isotopic forms of a given element have the same atomic number, but differ in atomic weight. Because of the existence of isotopes we now define an element as a pure substance, all of whose atoms have the same atomic number.

### Uses of Radium

Shortly after the discovery of radium those experimenting with its compounds, such as the bromide and sulfate began to develop cutaneous sores which proved to be extremely difficult to heal Investigation showed that the radioactive rays would also destroy bacteria and other similar organisms much more rapidly than they would injure healthy tissue. This property of radium makes it useful in the treatment of disease, notably ringworm, cancer, and other growths. Radium has proven effective in the treatment of many skin diseases, chronic infections, and to some extent in reducing scars.

Research indicates that malignant cells in their very rapid growth are particularly sensitive to the rays, and, as a consequence, radium may be used to inhibit or destroy the growth of those pathogenic cells, which are cancer cells and grow and multiply rapidly. Of the many varieties of cancer the rapidly growing type can be most successfully treated with x rays and gamma rays. In some cases the greatest benefit may come from combined surgery and ray treatment. To a certain extent, healthy tissue may be injured, particularly if the exposure to radiations is too frequent or prolonged. For this reason, in radium therapy an attempt is usually made to protect healthy tissue from the destructive action of the radiations by the use of shields which are impervious to the rays. Lead metal may be employed for this purpose. The objective in the use of radium is to produce the greatest amount of destructive action on pathogenic cells with the least possible injury to the normal cells of the body. Radium is kept in steel bombs which are lined with lead to prevent the escape of the penetrating, destructive radiations. It has been observed that the absorption of radium compounds in the body is dangerous, since these compounds tend to accumulate in the bones and disintegrate them.

In addition to its therapeutic uses, minute quantities of radium, mixed with fluorescent substances (zinc sulfide), have an application in making luminous enamels and varnishes for watch and clock hands, instrument dials, and other small objects which it is desirable to have luminous in the dark. Mesothorium, a disintegration product from the radioactive element thorium, is to some extent replacing the use of radium for such luminous preparations.

In some hospitals the radioactive gas radon (radium emanation), which is formed by the disintegration of radium, is used in place of the more expensive radium. The radon is sealed in short needle-like tubes of glass or gold, called "seeds," which can be inserted directly into malignant growths. The lower cost, intensity of radiation, and the ease with which radon tubes may be imbedded in a malignant growth or applied to a limited area make this radioactive gas very suitable for therapeutic purposes. However, radon is rather short-lived and loses one-half of its activity in 3.85 days. In contrast, radium has a half-life period of 1590 years.

It should be quite obvious that safe and successful radiotherapy demands a high degree of knowledge skill, and experience. Serious if not fatal injury may result from  $\mathbf{x}$  rays and radioactive materials in the hands of the careless or inexperienced operator

#### SELE-TESTING OUESTIONS

- 1 How are x rays produced?
- 2 Describe the experiment of Becquerel which led to the discovery of radium
  - 3 Define natural radioactivity and describe the rays given off by radio active elements

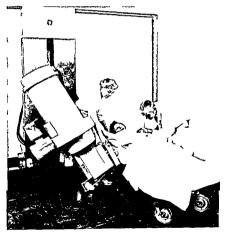


Fig. 4—An x ray unit being positioned for x ray therapy. Observe the painstaking care being exercised for proper positioning. Courtesy. General Electric Company.

- 4 Select several sets of isotopes from the uranium I disintegration series, other than the case already given as an illustration
- 5 What radiation from radium is effective in its therapeutic applications?
  6 What precautions are necessary in the use of radium?
- 7 Tell how radon is obtained and in what way it may be used
- 8 Just why is it possible in many cases to substitute x ray treatment for radium treatment?
- 9 Define or explain the following isotope, radium emanation, half life period

### III. NUCLEAR REACTIONS

### Nature of Nuclear Reactions:

The nuclei of atoms are made up of protons, neutrons, alpha particles, and possibly other structural units It would seem possible therefore, that bombardment with fast moving particles could

#### IMPORTANT PARTICLES IN NUCLEAR STRUCTURES

Particle	Approximate Mass	Charge	Symbols
Proton	1	+1	+, p, 1p1, 1H1
Electron	0 00055	-1	-; ε, β, -1ε°
Positron	0 00055	+1	β+, +1€°
Neutron	1	0	n, on1
Alpha particle	4	+2	α, 2He4

dislodge such structural units from the nucleus Scientists have been successful in doing this By employing machines such as the electrostatic generator and the cyclotron, charged particles like the proton, alpha particle, and deuteron (nucleus of deuterium) can be accelerated to very high velocities. Such powerful missiles have been used to disintegrate practically every element. The particle which strikes the nucleus becomes at least momentarily a part of it; a nuclear reaction may then occur with the formation of new nuclei. Such nuclear reactions might be described as transmutations, a dream of alchemists in the very early history of chemistry.

One of the first reactions of this type to be studied was the bombardment of nitrogen with alpha particles. This nuclear reaction is illustrated with an equation not unlike a chemical equation

$$_{7}N^{14} + _{2}He^{4} \rightarrow _{1}H^{1} + _{8}O^{17}$$

The superscript above and to the right of each symbol shows the atomic weight. The atomic number is given by the subscript below and to the left of the symbol. Thus, when an alpha particle (nucleus of the helium atom) strikes the nucleus of a nitrogen atom a reaction occurs which results in an oxygen atom of mass 17, and a hydrogen nucleus (proton). The alpha particles (£He') for this reaction are shot out of the nucleu of certain radioactive atoms in the course of their natural disintegration. The number of nuclear luts in this type of bombardment, compared to the number of misses, is very small, only about 1 alpha particle in 10,000 strikes a nitrogen nucleus.

Another very effective bombarding particle is the neutron. Since this particle carries no net charge it is not repelled by a positive nucleus or by the planetary electrons around a nucleus. A great many nuclear reactions have been carried out with the neutron as the bullet for penetrating the target. Neutrons for such processes are produced in certain nuclear transformations as typified by the following.

In this transmutation, alpha particles have been employed to convert beryllium of mass 9 into carbon of mass 12. The neutrons (an') released in the process become in themselves excellent projectiles for subsequent nuclear changes

One such transformation occurs when nitrogen is bombarded

## IV. ARTIFICIAL RADIOACTIVITY

### Production of Radioisotopes:

In 1934 Irene Curie Johot, daughter of Madame Curie, and M Johot observed that some of the lighter elements such as boron, magnesum, and alumnum became radioactive after bombardment with alpha particles. When the bombardment ceases the product is found to have a short lived activity, which is characterized as artificial or induced radioactivity. As an allustration, when alumnum is bombarded with alpha particles a radioactive isotope of phosphorus with a mass of 30 results. This isotope decays rapidly, having a half life period of 25 minutes. The formation and decay of radioactive phosphorus are expressed in the following equations.

$$_{13}Ai^{27} + _{2}He^{4} \rightarrow _{15}P^{30} + _{0}n^{1}$$
 $_{15}P^{30} \xrightarrow{\text{(half life}=2.5 min.)} _{14}Si^{30} + _{+1}e^{0}$ 

An interesting case is the transmutation of magnesium into a radioactive isotope of sodium. The sodium has a half-life period of approximately 15 hours, and by loss of a beta particle, reverts to the original magnesium. This is summarized in the following nuclear equations:

$$\begin{array}{c} {}_{12}{\rm Mg^{24}} + {}_{0}{\rm n^{1}} \rightarrow {}_{11}{\rm Ng^{24}} + {}_{1}{\rm H^{1}} \\ \\ {}_{11}{\rm Ng^{24}} \xrightarrow{\quad \text{(half life=15 hrs.)}} {}_{12}{\rm Mg^{24}} + {}_{-1}{\rm e^{0}} \end{array}$$

Over 800 artificially radioactive isotopes have been prepared from stable isotopes by nuclear reactions similar to the ones illustrated.

# Radioisotopes in Medicine and Nutrition:

Chemically and biologically, radioisotopes behave like their stable isotopes, but differ in that they can be detected, even in minute



Fig 5—Geiger counter used by man at left to keep a check on radioactivity while a small amount of radioadine is being withdrawn for placement in small flack at right. Why is flask walled off by the lead bricks? Courtery of University of Chicago.

quantities, with the electroscope (Geiger counter), an instrument which is sensitive to radioactivity. This provides a method for tracing and studying chemical reactions taking place in the body Thus, if a trace of radioactive calcium is added to the food it becomes possible to determine where the calcium is deposited in the body Many interesting and valuable facts concerning the complex chemical reactions of life processes have been brought to light 15P32, a radioactive isotope of phosphorus, prepared by nuclear bombardment, and having a half life period of about 14 days, is used in chronic leukemia (lymphatic, myeloid) studies in which condition the white cells become too numerous. The circulation of the blood can be studied by the intravenous injection of radio sodium in the form of sodium chloride, in surgery the rate of circu lation may be the deciding factor in cases where amoutation seems necessary It is now known from investigations with radioactive iron that the human system in normal health retains its iron. absorbing and excreting little, but in an anemic condition iron is absorbed rapidly Use of a radioactive isotope of iodine (iodine 131) as a "tagged atom" makes possible a study of the function of iodine in diseased thyroid glands Radiocarbon (C14) will un doubtedly prove to be a useful tool in biochemistry for learning more about the fate of carbohydrates fats, and proteins in digestion and metabolism

Cobalt 60 is an active source of powerful gamma rays, and it is used today in much the same way as radium and radon. Compared to radium, cobalt 60 is cheaper and easier to manipulate, and its samma radiation is more homogeneous.

In overactivity of the thyroid gland, Graves' disease for example, the highly selective power of the thyroid gland for iodine (I\*17), with the ensuing disintegration of the iodine isotope into beta and gamma rays to destroy overactive tissues, has benefited patients. Use of radioiodine to determine thyroid function can serve as an indication of a patient's metabolic state. All of this is a tribute to atomic medicine.

Such radioisotopes as C<sup>14</sup>, P<sup>32</sup>, S<sup>32</sup>, and Ca<sup>43</sup>, all of which have half life periods greater than 12 days, have been made available to research organizations, hospitals, climics, and medical colleges for therapeutic and tracer applications. In the field of medicine and nutrition it is likely that such isotopes will find their greatest use not as therapeutic agents but rather as tools for tracing disease and studying biochemical reactions. Thus the discovery and availability of radioactive isotopes have thrown open an entirely

new field of investigation with special significance in biochemistry. Some radioisotopes which have use in medicine and in biochemical research are listed here.

Name	Half life
Calcium 45	180 days
Carbon 14	5740 years
Cobalt-60	5 2 years
Iodine 131	8 days
Phosphorus 32	147 days
Sodium 24	15 hours



Fig. 6—The atom c bomb hit on Nagasaki heralds a new age of power from the atom. (Acme Photo.)

# V. NUCLEAR ENERGY

The large scale release of nuclear energy was revealed in the use of atomic bombs in 1945. This came as the culmination of several decades of research, greatly intensified in the last few years by the pressure of war. The terrible destruction wrought in the cities of Hiroshima and Nagasaki is ample proof of the enormous quantity of energy set free in atomic disintegration.

### Source and Magnitude of Nuclear Energy

The energy of ordinary chemical reactions is associated with the whirling, planetary electrons which occupy space beyond and around the compact, highly dense nucleus of the atom. In the processes of combustion of coal and explosion of suppowder the energy released is restricted to forces outside the nuclei, the nuclei themselves remain intact. The far greater energy stored in the nucleus is released only when bombarding particles invade it, and break down the enormous forces binding together protons and neutrons. The magnitude of this nuclear energy can better be appreciated when it is realized that one pound of uranium 235, an isotope of the element uranium, upon nuclear disintegration (fission) will liberate energy equivalent to that released by burning 1500 tons of coal Stated in another way, one gram of this same isotope will release energy equivalent to 20 billion calories of heat. In the generation of such nuclear energy about one thousandth part of the original mass disappears to provide it. Many years before nuclear energy was tapped, Einstein had shown that matter can be converted into energy under certain extreme conditions. We are now led to the conclusion that matter is in reality a form of energy

ISOTOPES OF URANIUM
(Nuclear structures n = neutron, p = proton)

92p 146n	92p 143n	9/2p 142n
U <sup>238</sup> at wt = 238 at. no = 92 99 2%	U235 at wt = 235 at no = 92 0.7%	U <sup>234</sup> at wt = 234 at no = 92 less than 0 01%

# Splitting the Uranium Nucleus:

Uranium, atomic number 92, has been the basis in the development of nuclear energy. Natural uranium ores, regardless of source, contain the three isotopes of the element in fixed proportions. These isotopes are designated as U<sup>238</sup>, U<sup>235</sup>, and U<sup>234</sup>, and are present to the extent of approximately 99.2 per cent, 0.7 per cent, and less than 0.01 per cent respectively.

 $\rm U^{225}$  has been used directly as a source of nuclear energy. Another isotope  $\rm U^{233}$ , which constitutes over 99 per cent of all natural uranium, is used as the raw material for the synthesis of an element named plutonium. Like  $\rm U^{235}$ , plutonium has proved to be a valuable source of energy.

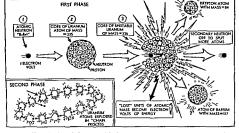
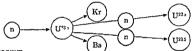


Fig. 7—How The Atom Is Split. Modified drawing appearing in American Weekly, issue of Sept. 3, 1945.

The separation of U<sup>235</sup> from its more stable isotope, U<sup>238</sup>, is not possible through chemical reactions inasmuch as all isotopes of a given element exhibit identical chemical behavior. It has been necessary therefore to resort to physical methods of separation; methods which in this instance are based on the slight difference in mass of the two isotopes. A discussion of these procedures is beyond the scope of this book; suffice it to state that methods employing gaseous diffusion, the principle of the centrifuge, the use of the mass spectrograph (electromagnetic method), thermal diffusion, and others have been investigated and used with varying degrees of success. All are laborious and time consuming. Scientists who

developed the atomic bomb necessarily gave considerable attention to the problem of separating the rather rare  $U^{235}$  from the more abundant  $U^{238}$ 

When the nucleus of a U<sup>225</sup> atom is invaded by a relatively slow moving neutron, fission of the nucleus occurs, with the formation of lighter atoms. Also important is the release of nuclear energy and several neutrons. Such neutrons become projectiles for splitting additional U<sup>225</sup> nuclei. The fission process in a sense provides its own ammunition, and in this way a self sustained or chain reaction may be set in motion. If conditions are such that the number of effective neutron impacts on U<sup>225</sup> nuclei progressively increases, and the heat is not dissipated as rapidly as generated, the process will attain explosive proportions as it does in the atomic bomb. There are a number of possibilities in the fission of U<sup>225</sup> nuclei, one of the more usual is pictured as follows.



### Plutonium

Another approach in the release of nuclear energy has been the preparation of a new element, plutonium from Uzis Inasnuch as plutonium is not an isotope of uranium, but a distinct element, it becomes possible to separate it by chemical methods. The proced ure for its synthesis is the bombardment of Uzis with neutrons to produce unstable, short lived Uzis. This isotope of uranium, artificial in character, upon loss of beta particles becomes the new man made element plutonium, atomic number 94. Plutonium is known as a trans uranic element and it has a very long half life pierod.

In equation form these changes are represented as follows  ${}_{92}U^{238} + {}_{01}{}^{1} - \cdots \rightarrow {}_{92}U^{239}$ 

Another element named neptunium, atomic number 93 and hence a trans uranic element, is produced as an intermediate in the con version of U<sup>238</sup> into plutonium. This element is not represented in the preceding simplified picture.

The device used to produce plutonium from U<sup>238</sup>, and at the same time control the rate of the reaction, is called a "pile" A pile is a combination of uranium and "moderator" such as carbon, it is constructed by placing rods of uranium in blocks of graphite The graphite captures relatively few neutrons, but serves to slow them down from the velocities they attain in nuclear fission to a point where they are more likely to be captured by U<sup>238</sup> nuclei or produce fission of U<sup>235</sup> Materials may also be incorporated in the pile to absorb neutrons harmlessly and prevent chain reactions from progressing too rapidly The heat which is generated must be removed to prevent excessive temperatures. Piles, now commonly called nuclear reactors, are being constructed throughout the world to produce power. New submarines are driven by atomic power plants.

# Hydrogen Bomb.

As has been noted, the process of nuclear fission, popularly referred to as "splitting the atom," releases tremendous quantities of energy. In more recent years it has been discovered that certain very light weight nuclei can be made to fuse into heavier nuclei with the conversion of mass into even greater concentrations of energy. This has led to the development of a hydrogen bomb which derives its energy from the fusion of hydrogen nuclei to produce helium nuclei. Considerable energy is needed to start the fusion, this energy may be provided by an unitial fission process.

Nuclear fusions are going on in the sun, and this becomes the source of much of the energy which we receive from the sun's radiations

# Physiological Effects

The effects of atomic bomb explosions on life have been studied at Hiroshima and Bikim, and in subsequent experimental explosions. The destruction of life is not due solely to the concussion set up by the explosion itself. Harmful radiations, such as neutrons and gamma rays, travel from the center of the explosion with speeds comparable to that of light. To the present time the only effective

measures for protection against such rays are heavy walls of steel, concrete, and similar massive materials, or considerable distance.

The gamma rays, in effect super x rays, are immediately destructive to life. The danger from neutrons is due to a secondary effect, since these particles impart artificial radioactivity to many elements. The sodium which is found throughout the body becomes radioactive under the impact of neutrons, and in such a state emits gamma radiations. The phosphorus which is an integral part of bones and certain tissues is another element made radioactive by bombardment with neutrons. Loss of white blood cells results, and the system has then little or no resistance to infectious disease. In studies conducted at Bikini, where experimental animals were exposed in the vicinity of the explosion, it was observed that in some cases the physiological effects were delayed for as much as two weeks. Thus the body after exposure to neutron radiation may become its own source of death.

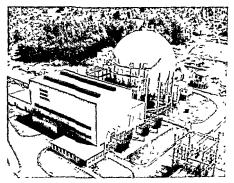


Fig 8—Production of Electricity from Nuclear Energy This pictures the most modern method of general ne electricity. What are other peacetime uses of nuclear energy? Courtesy, of Yankee Atomic Electric Company

The peacetime testing of atomic bombs and thermonuclear devices by exploding them in or above the atmosphere has been of grave concern to the governments and peoples of the world. The radioactive dusts created by the explosions are carried for hundreds of miles by the prevailing winds. Gradually the particles settle out of the atmosphere and over the surface of the earth to create a health hazard. Of particular concern has been the radioisotope called strontium 90, which has a half life of twenty seven years. Formed as a radioactive dust it settles in time and contaminates food crops and pasture lands. In the body, strontium 90 seeks out bone structure. When the atmosphere is known to be contaminated with radioactive debris it is a practice to periodically check the Sr 90 level in milk.

Without a doubt the release of nuclear energy is one of the greatest discoveries in recorded history, how it is used will no less certainly determine the fate of mankind. Science has placed in the hands of man untold power. If this is properly directed in peace time pursuits, much is promised for the welfare of the human race.

#### SELF-TESTING QUESTIONS

- 10 What are the projectiles which scientists have used for penetrating nuclei of atoms? What are sources of such particles?
- 11 How may charged particles be given greater velocities?
   12 Name and describe the particles which are important in nuclear
- structures

  13 What is the distinction to be made between natural and artificial
- radioactivity?

  14 Why is the separation of the isotopes of uranium restricted to physical
- methods?

  15 Why can plutonum be separated from uranium isotopes by chemical
- methods?
- 16 Why is strontium 90 a potentially dangerous isotope?

### SUGGESTED ACTIVITIES

- I THOUGHT PROVOKING QUESTIONS
  - 1 How does the energy of the ordinary chemical reaction compare with nuclear energy? What is the source of each?
    - Describe the production of radioisotopes and cite examples to show their importance in biochemistry
    - 3 Write an equation to illustrate the following nuclear transmutation boron mass 10 disintegrated with an alpha particle yields an isotope of nitrogen mass 13 and a neutron
    - 4 Discuss the physiological effects of the radiations released in large scale nuclear disintegrations

anhydride (an hi dride) An oxide which on addition of water becomes
(a) an acid or (b) a base

EXAMPLES (a) SO<sub>3</sub> + H<sub>2</sub>O  $\rightarrow$  H<sub>2</sub>SO<sub>4</sub> (b) CaO + H<sub>2</sub>O  $\rightarrow$  Ca(OH)<sub>2</sub>

anhydrous (an hi drus) Without water

EXAMPLES Blue vitriol or washing soda after losing water of hydration

anoxia A condition in which the cells are not obtaining a sufficient supply of oxygen

atom The smallest particle of an element taking part in a chemical change

EXAMPLE The smallest particle of sodium that can

combine with chlorine is an atom.

•• A substance containing the group OH, the water solution of which gives hydroxyl ions

EXAMPLES NaOH, NH4OH, Ca(OH)2, Mg(OH)2

basic salt A compound formed when only part of the hydroxide radicals of a base are replaced by the acid radical of an acid EXAMPLES BI(OH)<sub>2</sub>NO<sub>6</sub>, Pb(OH)<sub>NO<sub>8</sub></sub>

binary acids (binare) Acids containing hydrogen and one other element  ${\tt EXAMPLES} \ \ HCl, H_2S$ 

buffer saits Salts in the blood which counteract the action of acids or bases EXAMPLES NaHCO3, Na2HPO4, NaH2PO4

cal orie (small) The unit of heat which is required to raise the temperature of one gram of water one degree centigrade

catalytic agent (kat al it ik). A substance that changes the speed of a reaction without itself undergoing a permanent change

EXAMPLE Manganese dioxide in the preparation of oxygen

chemical change. One in which the composition of a substance has changed. It involves an alteration in physical and chemical properties

colloid (kol oid) A substance the particles of which are intermediate in size between coarse suspensions and molecules

EXAMPLE Gelatin (a colloid) has particles or films smaller than clay (a suspension) and yet larger than the molecules of salt dissolved in water

combustion A rapid chemical action producing light and heat
EXAMPLE Burning of wood
compound A combination of two or more elements

EXAMPLE  $C + O_2 \rightarrow CO_2$ 

cotalence (kö-va' löns) The chemical binding of atoms through sharing of electrons

destructive distillation Process of decomposing complex organic compounds by heat in the absence of air, and condensing the vapor of the liquid products

#### EXAMPLE Heating soft coal

dialysis (di al 1 sis) The separation of a crystalloid from a colloid by use of a membrane

diffu'sion Process by which a substance in solution distributes itself uniformly throughout the solvent

distilla'tion The separation of a liquid from a mixture by boiling and con densing the vapor

EXAMPLE In the distillation of impure water, the pure
water is separated from its impurities

electrolysis (e-lek trol i sis) The decomposition of a substance in a solution by the electric current

EXAMPLE The electrolysis of water to yield hydrogen and oxygen

electrolyte (e-lek tro lite) A substance the solution of which conducts the electric current and is decomposed by it

EXAMPLES Hydrochloric acid, sodium hydroxide, sodium chloride

electron (e-lek'tron) Particle of negative electricity

el ement One of some one hundred simple substances which are the basis for chemical changes

EXAMPLES Oxygen, hydrogen, sodium gold and iron are elements

emul sion A suspension of a finely divided liquid in another liquid

equation A symbolic representation of a chemical reaction

fluorescence Property a body possesses of emitting light while exposed to the action of certain rays

for'mula An arrangement of symbols so as to represent the composition, number, and variety of atoms in a molecule A symbolic representation of a molecule

gel (jel) Semisolid condition of a precipitated or coagulated colloid

halogen (hal o-jen) This term means salt former and refers to the elements F, Cl, Br, or I

hemolysis (he-mol i sis) The result of water passing into a blood cell thereby causing it to swell and burst

hydrate (h. drate) A crystalline substance containing a definite amount of water in combination,

EXAMPLE Plaster of Paris (CaSO4)2 H2O

hydrocar'bon A compound which contains hydrogen and carbon only EXAMPLE Ethylene, C<sub>2</sub>H<sub>4</sub> hy'drogen ion or pH scale A means of indicating accurately any degree of acidity or alkalimity.

hydrolysis (hi droi i sis) Any chemical reaction of an element or a compound with water

hydrophilic A liking for water, a type of colloid

hyperton'ic Pertaining to a solution of higher osmotic pressure than another hypoton'ic Pertaining to a solution of lower osmotic pressure than another

hypoxia An inadequate supply of oxygen for metabolism

ton An electrically charged atom or radical in solution. The loss or gain of one or more electrons by an atom or group of atoms (radical) produces an ion

EXAMPLE Na+, Cl-, SO,-, NH,+

isoton'ic Pertaining to two solutions having the same osmotic pressure
EXAMPLE Physiological saline solution is isotonic to the blood

isotopes Atoms of an element which differ only in mass. All isotopes of a given element have the same atomic number

kindling temperature The lowest temperature at which a substance ignites

EXAMPLE The kindling temperature of phosphorus is 37° C

metal A base forming substance An element which loses electrons during chemical changes

EXAMPLES Na. Ca. Mg

mole A gram formula weight of a substance

during chemical changes

EXAMPLE One mole of SO2 is 64 grams

molecule (mol'e-kule) The smallest particle of a substance that can exist and still retain the properties of that substance

EXAMPLES O2, H2O

neutralization The combination of the hydrogen ions of an acid and the hydroxyl ions of a base to form undissociated water

EXAMPLE  $Na+OH^- + H+Cl^- \rightarrow Na+Cl^- + H_2O$ 

neutron A close union of proton and electron, which has no electrical charge nonmetal. An acid forming substance. An element which gains electrons

EXAMPLES C1, S

nonpolar compound. A compound in which the centers of positive and negative charge coincide

normal sait. The compound formed when all of the hydrogen of an acid is replaced by a metal

EXAMPLE Na<sub>2</sub>CO<sub>3</sub>

osmosts (os mo'sis) The passage of a liquid through a membrane

oxida'tion The process by which a substance combines with oxygen, more generally oxidation involves a change from a lower to a higher positive valence

EXAMPLES 2 Cu + 
$$O_2 \rightarrow 2$$
 CuO  
(Cu° - 2  $\epsilon \rightarrow$  Cu<sup>++</sup>)

oxide (oks'ide) A compound consisting of oxygen and one other element EXAMPLE CaO, Na<sub>2</sub>O, H<sub>2</sub>O

pep'tize To disperse an insoluble material into particles of colloidal size EXAMPLE Pepsin changes protein to peptones

photosynthesis (fo to sin'the sis) A synthetic process by which plants manu facture carbohydrates

plasmolysis (plaz mol i sis) The result of the passing of water out of a cell, thereby causing the cell to shrink, also called crenation

polar compound Compounds in which the centers of positive and negative charge are separated

pro'ton A fundamental particle of positive electricity

rad'ical A group of elements acting as a unit

radioactive Pertaining to any substance that emits radiations through spon taneous transmutation

#### EXAMPLE Radium

reduction. The process of taking oxygen from a compound more generally a change from a higher to a lower positive valence

EXAMPLE 
$$CuO + H_2 \rightarrow Cu + H_2O$$
  
 $(Cu^{++} + 2 \epsilon \rightarrow Cu^{\circ})$ 

salt A compound consisting of a positive ion other than hydrogen and a negative ion other than hydroxyl (Salts may be formed in several ways, see text)

saturated solution One which contains all the solute that can normally be dissolved at that temperature

semipermeable (per me a ble) Pertaining to a membrane which will allow certain substances but not others, to pass through it

solute (so lute') The dissolved substance in any solution

solution (so lū'shun) A molecular or ionic dispersion

sol vent The substance in which anything is dissolved

specific gravity The ratio of the weight of one cubic centimeter of a substance to the weight of one ml of water

EXAMPLE Sp Gr of urine is about 1 02

specific heat The number of calories absorbed or given up when one gram of a substance changes its temperature I° C

EXAMPLE Sp Ht of water is 1

spontaneous combustion Ignition without the external application of heat Example Spontaneous combustion of coal dust.

suspensoids The suspended particles

EXAMPLE Particles in river water

symbol An abbreviation for an element

EXAMPLES H for hydrogen Cu for copper

synthesis (sin the sis) The umon of elements to produce compounds  $EXAMPLE C + Q_2 \rightarrow CQ_2$ 

ternary acid (ter na re) Inorganic acids containing hydrogen and two other elements

EXAMPLES H2SO4 HNO3

valence (valens) 1 The number indicating how many atoms of hydrogen can unite with one atom of another element 2 The number indicating how many electrons an element or radical has gained lost or shared through chemical action

EXAMPLE In H<sub>2</sub>SO<sub>4</sub> the H has a valence of 1 and the SO<sub>4</sub> a valence of 2

x rays Radiations produced by electrons from the cathode striking a target

#### PART II

# ORGANIC CHEMISTRY

#### THE CHEMISTRY OF THE HYDROCARBONS AND THEIR DERIVATIVES

Replacing diseased arteries with synthetic materials is a major triumph of surgery This one is made of 'Teflon," a fluorocarbon Courtesy, DuPont Magazine, Copyright, 1958, E 1 du Pont de Nemours and Company



### INTRODUCTORY WOTES

### TO THE INSTRUCTOR

In this division of chemistry, we are to study that large class of compounds which contains the element carbon if will become an interesting and fascinating study for the student nurse when it is realized that life with all its mysteries dwells permanently among carbon compounds. Those facts, laws, and theories developed in the previous chapters will govern the formation and behavior of most organic compounds. Just as there are oxides, acids, bases, and salts in inorganic chemistry, so there are similar compounds in organic chemistry, but with the main difference that the carbon compounds are weakly electrical in nature. This is largely due to the fact that the carbon atom never exists as an ion in solution, but rather shares its electrons with carbon atoms or atoms of other elements.

The discussion starts with the compounds of hydrogen and carbon, and then it branches to the study of substitution products or derivatives, which are considered as compounds formed by replacing one or more hydrogen atoms in the hydrocarbon molecule by radicals which have characteristic properties. Some of the most frequently substituted radicals which impart new properties are the alcohol group (—OH), and the aldehyde group (—CHO), the ketone group (=CO), the acid group (—COOH), and the amino group (—NH).

Since organic chemistry is the chemistry of most articles of everyday life, such as food, clothing, medicines, dyes, perfumes, and flavors, this study in addition to its fascination and interest will be the background for an intell gent interpretation of the chemical changes constantly occurring in the human body (Part III)

### ORJECTIVES

### I. FACTS AND PRINCIPLES

- (a) To learn that the properties of carbon make possible some 500,000 carbon compounds
- (b) To know that organic compounds may be divided into classes showing similarity in composition and properties
- (c) To learn that the principles governing the formation and behavior of inorganic compounds apply as well to organic compounds
- (d) To learn that the classification and properties of organic compounds depend largely upon the presence of characteristic groupings in the molecule
- (e) To predict from the formula how an organic compound might behave, and to some extent the possibility of its use
- (f) To become acquainted with the uses of a variety of important carbon compounds

## II. ATTITUDES

- (a) To develop an appreciation of the work of the chemist in producing many valuable substances from plants and animals
- (b) To realize that, in all problems of the future, chemistry with its background of allied sciences is the one science capable of solving many of life's problems
- (c) To realize that to chemical research we owe much for our health and happiness.
- (d) To realize that an understanding of organic chemistry is fundamental to the appreciation of many practical human interests whether domestic or industrial
- (e) To realize that organic chemistry is worthy of study from the cultural as well as the scientific standpoint

### CHAPTER XII

# SOME GENERAL FACTS. THE HYDROCARBONS

### CHAPTER OUTLINE

- I INTRODUCTION
  - (a) The origin and importance of organic chemistry
  - (b) Differences between morganic and organic compounds
  - (c) Sources of organic compounds
- II STRUCTURAL THEORY OF ORGANIC COMPOUNDS (a) The carbon atom
  - - (b) Classes of organic compounds
- III THE HYDROCARBONS
  - (a) Classification
  - (b) The methane series (c) The hydrocarbon radicals
  - (d) Sources and properties of the paraffin hydrocarbons
  - (e) The ethylene series of hydrocarbons

- (f) Sources and properties of the ethylene series of hydrocarbons
- (g) The acetylene series of hydrocarbons
- (h) Three typical aliphatic hydro carbons
- (i) The cycloparaffins Cyclopro-
- (1) The aromatic hydrocarbons Benzene
- IV HALOGEN DERIVATIVES
  - (a) Some common halogen substitution products
  - PETROLEUM
    - (a) Composition of petroleum
    - (b) Refining of petroleum

## I. INTRODUCTION

# The Origin and Importance of Organic Chemistry:

About the beginning of the nmeteenth century chemists were becoming increasingly aware of a rather large number of compounds which were associated with plants and animals. For a number of years the general conclusion prevailed that these compounds could be synthesized only through life processes. This led to the vital force theory. Inasmuch as this theory rested on the assumption that the living organs and tissues in plants and animals produced these substances, they came to be known as organic compounds, and the branch of chemistry which dealt with them was termed organic chemistry.

In 1828 a German chemist, Friedrich Wohler, succeeded in preparing urea by heating and evaporating a solution of ammonium cyanate

 $NH_4OCN \rightarrow (NH_2)_2CO$ 

Ammonsum cyanate

Urea is a product of body metabolism, and therefore a typical organic compound, ammonium cyanate, however, was known as an inorganic compound. Wohler's synthesis of urea was an important achievement in the history of chemistry because it marked the first time that a scientist had knowlingly prepared an organic compound from an inorganic one. Since the time of Wohler's work chemists have synthesized in their laboratories many compounds which are also produced in nature in the course of life processes Hence the older concept of vital force as essential has been dis proved. Since carbon is a necessary element in all organic compounds, organic chemistry is today rather simply defined as the chemistry of the compounds of carbon.

Actually a few compounds of carbon, because of their properties and relationships, are included in morganic chemistry. These are for the most part the oxides of carbon and the carbonates. A number of the latter are found in nature as minerals. To repeat, then, in its broadest sense, organic chemistry is the branch of chemistry which deals with the compounds of carbon.

The importance of organic chemistry is shown in the daily use of many products which are in themselves of organic composition or which have required the use of organic substances in the course of their manufacture. Of particular importance is the development of new medicinal compounds and improvement in purity of those drugs which occur in nature. The majority of dyes and perfumes and the fabrics used for clothing and furnishings are of organic composition. Fuels like gasoline, natural gas, and fuel oil are mix tures of organic compounds.

Equally as important, however, is that one must appreciate the fact that the major classes of foodstuffs, namely, faits, carbohydrates, and proteins, are organic compounds. This is true also of the vitamins. A primary reason for devoting some time to a study of the fundamentals of organic chemistry is to make it possible for the student to understand and better appreciate the chemical reactions which take place in the body. The processes of digestion and metabolism are chemical changes which involve the use and the production of compounds of earbon.

## Differences between Inorganic and Organic Compounds:

In addition to acquainting the student with the underlying laws and theories of chemistry the preceding chapters in this textbook have dealt with a few of the more important elements and their



Fig. 1—A Boy Made the First Aniline Dye. William It. Perkins in 1856, at the age of 17, while working with coal tar in his laboratory under the eaves of his English home, made the first synthetic dye "mouve." He was attempting to make quinine, but instead by accident made a beautiful violet-purple dye. What was the outcome of such a discovery? Courtes, Parke, Davis & Co., N. Y. C.

inorganic compounds. Since we are now to give some attention to organic compounds it is appropriate at this point to note certain significant differences between the organic and inorganic types.

ABUNDANCY: A recent estimate places the number of inorganic compounds on record as close to one-half million, and the number of organic compounds as nearing the two million mark. Luster we shall learn that carbon atoms share electrons with one another to establish covalent type of linkages. This is a primary reason for the excess of organic compounds over the inorganic ones.

STABILITY: In general, organic compounds have lower melting points and boiling points than do inorganic compounds. Also, organic compounds are usually less stable to light and heat than are the inorganic. For this reason, more sensitive organic compounds may be stored in colored glass containers, and kept under refrigeration

Solubility Many inorganic compounds are soluble in water Very few are appreciably soluble in organic solvents such as ether, benzene, and carbon tetrachloride. In contrast, numerous organic compounds are not soluble in water, but are readily soluble in organic solvents. However, these statements about solublity have numerous exceptions, and are therefore to be regarded as broad generalizations.

RATE OF REACTION Inorganic reactions tend to be very rapid, in many cases seemingly instantaneous, while organic reactions as a rule are slow This is due to the fact that many inorganic compounds are some structures while organic compounds are covalent. Iomic reactions are rapid, in contrast, covalent molecules usually react rather slowly To illustrate, the addition of a solution of silver intrate to one of sodium chloride gives an immediate precipitation of silver chloride. On the other hand the reaction of an alcohol with an organic acid takes place so slowly that often one must wait several hours before any considerable amount of product is obtained.

COMBUSTIBILITY Many organic compounds are combustible, and the vapors of some, when mixed with air, give explosive mix tures Some organic compounds when heated will first char, indicating the presence of carbon Very few inorganic compounds are combustible

NUMBER OF ELEMENTS In a study of morganic compounds many chemical elements are considered. In contrast, the organic compounds are built up from relatively few elements. Carbon and hydrogen alone account for thousands of compounds. Thousands more are restricted to carbon, hydrogen, and oxygen, these include the alcohols, ethers, carboxylic acids carbohydrates, fats and others. With possibly a few exceptions, carbon, hydrogen, oxygen, mitrogen the halogens, sulfur and phosphorus are the only elements that enter into the organic compounds to be studied in this course.

Complexity of Structure For the most part the organic compounds are much more complex in structure than are the morganic ones. There is usually a greater number of atoms in organic molecules, and often a given number of atoms can be arranged differently to give distinctly different compounds. Thus  $CaH_0O$  is the molecular formula for a certain ether and also the

molecular formula for one of the alcohols. This feature of organic chemistry, wherein two or more different compounds have the same molecular formula, is called isomerism. Notice that the molecular formula shows only the kind and number of atoms in the molecule, and not necessarily how they are arranged.

# Sources of Organic Compounds:

From plants and animals we obtain many of our organic compounds such as starches, sugars, fats, proteins, alkaloids, and dyes Many of these compounds, either through natural processes or laboratory synthesis, may be converted into other valuable organic substances Illustrative is the fermentation of sugar to produce ethyl alcohol The alcohol so produced may in turn be used to prepare a variety of useful compounds such as the anesthetics, ether and ethylene

Other organic compounds are obtained from coal, wood, petroleum oil, and bones by destructive distillation, a process of decomposing a substance by heating in the absence of air Coal tar, coal gas, and ammonia from coal, as well as acetic acid, wood alcohol, and acetone from wood, are formed through destructive distillation

More recently, many organic compounds have been made by synthesis from inorganic substances. For example, a synthetic rubber called neoprene is prepared indirectly from coke, lime, and other substances.

This brief discussion should make it clear that nature and the scientist in his laboratory work in conjunction to provide man with a wide variety of organic compounds

### SELF-TESTING QUESTIONS

- 1 What is the origin and the present meaning of the term "organic chemistry"?
- 2 What discovery led to the preparation of organic compounds?
- 3 In what way does a knowledge of organic chemistry contribute to (a) industry, and (b) to biochemistry?
- 4 Name and explain, giving examples, a number of ways in which organic and morganic compounds differ
- 5 What are the two general sources of organic compounds?
- 6 What compounds used in the hospital may be obtained from sugar?
- 7 What is destructive distillation? What products may be obtained by this process?
- 8 Why does carbon form so many more compounds than do other elements?

# II. STRUCTURAL THEORY OF ORGANIC COMPOUNDS

## The Carbon Atom:

Chains and rings of carbon atoms become the framework for organic molecules Carbon is invariably tetravalent, and this fundamental point must be kept in mind at all times when writing structural formulas

The structure of the carbon atom shows four valence electrons, that 15, four electrons in the outer shell When a carbon atom



Fig. 2—Carbon with its four valence electrons.

shares its electrons with other carbon atoms, or with atoms of other elements, forces of covalence are established

The compound methane, CH<sub>4</sub>, has the following structure In the methane molecule the carbon atom is sharing its four valence electrons with the hydrogen atoms, each of which in turn shares its one electron with the carbon In this way four covalent forces are established between the carbon and the hydrogen Outer electron shells thus become complete, the carbon atom having eight electrons around it, and each hydrogen two, but this is possible only by sharing valence electrons as common property



Fig. 3—The carbon atom shares with each hy dragen a pair of electrons one electron from the carbon and one from each hydrogen

Structures like that for methane are simplified by the use of the short straight line to represent each pair of shared electrons. This gives the structural formula. Notice that the short line, or valence bond, as it is called is merely a more convenient way of picturing a pair of shared electrons.

Fig. 4—S mpl fled structures for methane. On the left is the electronic structure. On the right the line bond replaces the pair of shared electrons.

Following are the electronic type formulas for ethyl alcohol and methyl ether Recall in examining these structures that the oxygen

atom has six valence electrons the carbon atom four, and the hydrogen atom one. Notice too that in each structure each of the carbon atoms has a total of eight outer shell electrons the oxygen eight, and the hydrogens two. However this attainment of stable numbers of electrons by the atoms involved is possible only by sharing. Observe that in each of these structures the oxygen atom shares but two of its six original electrons but by sharing two has a covalence of two.

These structures are simplified to give the more conventional structural formulas

When one condenses these structural formulas to molecular formulas the result for each is C<sub>2</sub>H<sub>6</sub>O Therefore these two compounds are isomers Isomers are compounds which have the same kind ard number of atoms in the molecule, but which differ in the arrange

ment of these atoms in the structure of the molecule From this it should be apparent that in organic chemistry the molecular formula alone is usually not adequate because it does not show how the atoms are arranged and linked together

## Classes of Organic Compounds.

As has been stated, there are many thousands of organic compounds, and the task of studying them individually would be an impossible one Fortunately, based upon structural similarities, it is possible to classify organic substances. Some of the more important and fundamental classes and types which are to be considered are given in the table.

### IMPORTANT CLASSES OF ORGANIC COMPOUNDS

Hydrocarbons	Carboxylic acids	Carbohydrates
Alcohols	Ethers	Fats
Aldehydes	Laters	Proteins
Ketones	Amines	
21002101		1

The carbohydrates, fats, and proteins become of particular im portance, and for this reason an entire chapter will be devoted to each Inasmuch as all organic compounds can be considered as derived from the hydrocarbons, we shall study the hydrocarbons in this introductory chapter

### SELE-TESTING QUESTIONS

- 9 What property of the carbon atom makes possible the formation of so many compounds of carbon?
- 10 What are isomers? Why must the organic chemist use structural formulas?
- 11 On what basis is it possible to classify organic compounds?
- 12 What does the single bond in structural formulas stand for?

## III THE HYDROCARBONS

### Classification

Since carbon has a valence of four it would seem that there would be but one hydrocarbon, namely, CH<sub>4</sub> However, we must note that carbon atoms can share electrons and in this way attach themselves in chains and rings Hundreds of hydrocarbons are known, and from structural considerations many thousands become

possible of existence and preparation. Hydrocarbons are organic compounds which are built up from carbon and hydrogen as the only elements. This statement about the composition of hydrocarbons should be kept in mind by the beginner in his approach to organic chemistry. In the study of hydrocarbons as well as other classes of organic compounds, emphasis will be placed on class properties. Based on structure, the hydrocarbons can be classified as shown in the accompanying table. The name and formula for the first member of each series is included in the table.

## A CLASSIFICATION OF HYDROCARBONS

	Aliphatic Hydrocarbon (Open Chain Structure	s s)
Methane series	Ethylene series	Acetylene series
(paraffins) Alkanes	(olefins) Alkenes	Alkynes
CH4	C <sub>2</sub> H <sub>4</sub>	C <sub>2</sub> H <sub>2</sub>
H—C—H H	H H H—C=C—H	HC = CH
Methane	Ethylene	Acetylene

### Cyclic Hydrocarbons (Ring Structures)

(Ring Structures)		
Cycloparaffins	Aromatics	
C <sub>3</sub> H <sub>6</sub>	C <sub>6</sub> H <sub>6</sub>	
н н н—с—с—н	H-C C-H	
Cyclopropane	Benzene	

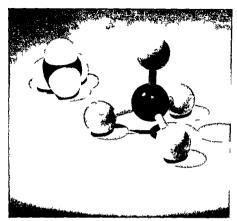


Fig. 5—Models of the Methane Molecule The model on the right is a ball and stick type while the one on the left is a scale model. What is the nature of covalence? Courtesy Tab as Studio Akron Ohio.

## The Methane Series

The table which follows gives names and other data for the first several members in the methane or paraffin series of hydrocarbons Hydrocarbons of this series are called alkanes in systematic naming

All members of this series must conform to the general or type formula  $C_{\rm b}H_{2+12}$  where n is the number of carbon atoms in the molecule Thus if a certain hydrocarbon contains seven carbon atoms then it must also contain  $(2\times7)+2$  or 16 hydrogen atoms in order to be a member of the methane series. A hydrocarbon of molecular formula  $C_{\rm b}H_{10}$  could not be classified as an alkane

The paraffin hydrocarbons represent a typical homologous series

etc

Name	Molecular Formula	Possible Structures	
Methane	CH <sub>4</sub>	1	
Ethane	C <sub>2</sub> H <sub>6</sub>	1	
Propane	C <sub>3</sub> H <sub>8</sub>	1 1	
Butanes	C4H10	2	
Pentanes	C5H12	3	
Hexanes	CoHia	5	

THE METHANE SERIES

of organic compounds. In any homologous series consecutive members differ by the amount of one carbon and two hydrogens, that is, by the unit —CH<sub>2</sub>— It is customary to refer to members of such a series as homologues. We shall find that homology is the nature of other classes of organic compounds

The listing given in the table is by no means complete for this series, it continues with an increasing number of carbon atoms in the molecules. Paraffin hydrocarbons having nearly one hundred carbon atoms in the molecule are known.

# Structures of the Methane Hydrocarbons. Isomerism

The table points out that there is one possible methane, one ethane, one propane, two butanes, and three pentanes. The two butanes, molecular formula  $C_4H_{10}$ , must have different structures and hence are isomers. The same situation exists for the three pentanes. Structural formulas follow

Examine carefully the structures for the two butanes and be certain that you understand wherein they differ Notice, for example, that in normal butane the carbon atoms are in one continuous chain, while in isobutane the longest continuous chain of carbons is three \* Hydrocarbons which have all of the carbon atoms in the molecule in one continuous chain are indicated in naming as normal, usually abbreviated as n— Both of the butanes are known, and they have different physical and, to some extent, different chemical properties. In a similar manner study the structures for the three isomeric pentaines

In the structures for the paraffin hydrocarbons it is to be noted that all bonds connecting carbons are single bonds, and that each bond stands for a pair of shared electrons. Hydrocarbons of this type are said to be saturated. We shall find that this is in contrast to the hydrocarbons which make up the ethylene and the acetylene series. The alkanes are saturated hydrocarbons.

As the number of carbon atoms in the molecule increases, the number of isomers possible increases rapidly. Theoretically there are seventy five isomeric decanes, all, however, have the molecular formula C<sub>10</sub>H<sub>20</sub>

### The Hydrocarbon Radicals:

In the study of morganic compounds it was learned that there are certain rather stable groups of atoms called radicals, for example the sulfate radical, SO<sub>4</sub>, and the ammonium radical, NH<sub>4</sub>. Similarly radicals exist in organic structures, and masmuch as some of these are comprised of only carbon and hydrogen, and are important in naming compounds and in writing formulas and equations, they are now considered Names and structures for a few of the simpler,

<sup>\*</sup>Models are helpful in learning to understand isomerism

but nonetheless very important, ones are listed in the table Notice that the radical is a part of a molecule, some atom or group must be attached to the radical to make a complete molecule Hydro carbon radicals of this type are known as alkyl groups

### SOME HYDROCARBON RADICALS

Radical Name	Structure	Condensed Structure
Methyl	н н_с_ н	CH <sub>3</sub> —
Ethyl	н н н-с-с- н н	C <sub>2</sub> H <sub>5</sub>
n Propyl	н н н н-с-с-с- н н н	CH₃CH₂CH₂—
Isopropyl	H H H H-C-C-C-H H H	(CH₃)2CH—
n Butyl	н н н н н-с-с-с-с- н н н н	CH4CH2CH2CH2—

Notice that there are two different propyl radicals, but only one propane. If one attaches a hydrogen atom to either of the propyl radicals the result is the same compound, namely, propane. How ever, if some atom other than hydrogen, or some group of atoms, is attached then different (isomeric) compounds result. There are, for example, two different propyl alcohols. One is called normal propyl alcohol and the other, its isomer, is isopropyl alcohol.

In addition to the n butyl radical there are three other butyl radicals. These are named isobutyl, secondary butyl, and tertiary butyl.

# Sources and Properties of the Paraffin Hydrocarbons:

The hydrocarbons of the methane series are obtained largely from natural gas and petroleum. The former is essentially methane, often over 80 per cent, with relatively small quantities of other hydrocarbons

Petroleum is an exceedingly complex mixture of compounds, pre dominantly liquid hydrocarbons. Quantities of gaseous hydrocarbons are dissolved in the liquids, and dissolved solids are also present. By the process of fractional distillation it is possible to separate petroleum into fractions which consist of mixtures of compounds having definite boiling point ranges. Gasoline and kerosene are typical fractions from petroleum oil

It is also a practice to convert some of the hydrocarbons which have the higher molecular weights into simpler hydrocarbons of smaller molecular weight by processes called "cracking". This requires the use of catalysts and usually elevated temperatures and pressures. The smaller molecular weight molecules obtained in this way are more volatile, and some are suitable for gasoline mix tures. Also, certain types of simple hydrocarbon molecules can be made to join together and give larger molecules. This is called polymerization. The vast petroleum industry can today by fractional distillation, cracking, and polymerization provide from crude petroleum oil the many industrially important hydrocarbon mixtures of which the various gasolines, fuel gases, and fuel oils are of outstanding importance.

The lower members of the alkane series of hydrocarbons are gases, beginning with those which have five carbon atoms, and extending to some having as many as twenty five carbon atoms in the molecule, they are liquids Higher members are solids, paraffin wax, for example, is a mixture of solid hydrocarbons. All hydrocarbons are insoluble in water

In general, the paraffin hydrocarbons are rather mert chemically. This is due in part to their saturated character. Thus, they may be treated with aqueous oxidizers, with strong alkalis, and even with concentrated mineral acids at room temperature without any chemical activity. Such lack of reactivity is an important property of the saturated hydrocarbons. The word paraffin in its derivation means "little affinity."

There are several characteristic chemical reactions of the alkanes, and two of these are to be considered here. One of these is combus

tion, or, as it is sometimes termed, high temperature oxidation. The parafiin hydrocarbons, and all other types of hydrocarbons for that matter, are highly combustible, they burn in oxygen, or in air which supplies the oxygen, to give carbon dioxide and water as the products of complete combustion. During this process, energy, predominantly in the form of heat, is liberated. This liberation of energy accounts for the widespread industrial and domestic uses of hydrocarbons and hydrocarbon mixtures as fuels.

An equation which expresses the combustion of ethane follows

Another type of reaction which is shown by the methane series of hydrocarbons is called *substitution* This involves the replace ment of one or more hydrogen atoms in the hydrocarbon molecule by one or more other atoms or radicals We shall confine our study of substitution to the use of chlorine and bromme, this can then be called *halogenation* The equations below illustrate substitution

Here all four of the hydrogens in the methane molecule have been replaced in a stepwise fashion by chlorine atoms. Notice that each of the reactions of substitution gives two products. The use of the halogens in substitution is confined to chlorine and bromme, iodine is not reactive with hydrocarbons, and fluorine proves to be so highly reactive that the organic structure is broken down. Replace ment of hydrogens in hydrocarbons by chlorine and bromine is favored by elevated temperatures and actinic light. Chloroform, carbon tetrachloride, etc., are not prepared commercially according to the reactions just given because, as is shown, a number of substi-

tution products are formed at the same time, and it is not economically feasible to separate them

## The Ethylene Series of Hydrocarbons:

The table gives the names and molecular formulas for the first several members in the ethylene series. This series of hydrocarbons is known also as the olefin series, and the members are termed alkenes.

### THE ETHYLENE SERIES

Name	Molecular Formula	Number oj Structures
Ethylene	C <sub>2</sub> H <sub>4</sub>	1
Propylene	C <sub>3</sub> H <sub>6</sub>	1
Butylenes	C <sub>4</sub> H <sub>8</sub>	3
Amylenes	C <sub>5</sub> H <sub>10</sub>	5
Hexylenes etc	C6H12	13

The olefin hydrocarbons are unsaturated, this is indicated in the structure of each olefin by the presence of one double bond between adjoining carbon atoms. The structural formulas which follow illustrate this important characteristic.

The double bond is the symbol employed for four shared electrons, or since electrons are shared in pairs the double bond stands

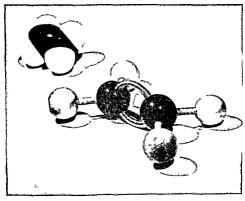


Fig. 6—Models of the Ethylene Molecule. How does the model show the unsaturation found in ethylene? Courtesy Tobias Studio Akron. Ohio

for two pairs of shared electrons. It is not to be considered as a point of structural strength and stability in the molecule actually the double bond is a center of chemical activity and the more characteristic chemical reactions of these hydrocarbons involve the point of unsaturation.

In addition to the structures for ethylene and propylene the structures for the three butylenes are given primarily to point out that the molecular formula C.Hs represents three isomeric unsaturated hydrocarbons Observe also that the olefin series is a homologous series of hydrocarbons The general formula for this series to which all members must conform is C<sub>n</sub>H<sub>2n</sub>

# Sources and Properties of the Ethylene Series of Hydrocarbons

Unlike the paraffin hydrocarbons the alkenes occur in nature only in traces for example very small quantities of ethylene are found in natural gas. However large quantities of the olefins can

be made commercially by cracking the paraffin hydrocarbons (See page 266) The equation which follows gives a somewhat simplified version of how a butylene (I butene) might be formed by cracking normal octane

The olefins of lower molecular weight are gases those of five carbon atoms they become liquids Like all hydrocarbons, the alkens are insoluble in water.

The members of the ethylene series, principally because of the double bond which gives them unsaturation, are far more reactive than the paraffins. The olefins are combustible and, like all other hydrocarbons, if the supply of oxygen is adequate, they burn to give carbon dioxide and water with liberation of energy, largely as heat. By way of illustration, propylene gas burns according to the following equation.

2 C<sub>3</sub>H<sub>5</sub> + 9 O<sub>2</sub> 
$$\rightarrow$$
 6 CO<sub>2</sub> + 6 H<sub>2</sub>O + energy Propulere

The most typical chemical reaction of the alkenes is called addition. Because of unsaturation it is possible for these hydrocarbons to add such substances as hydrogen, chlorine, and bromine. In the course of the addition the double bond gives way to a single bond, and hence the unsaturation disappears and the product of the reaction is saturated. Ethylene and its homologues, under proper conditions which include the use of a catalyst add on hydrogen.

The addition of bromine to ethylene proceeds as follows

The addition of chlorine and bromine to unsaturated hydrocarbons is favored by low temperature and the absence of light. Notice that in the addition type of reaction only one product is formed. The student should at this point contrast substitution with addition, turning back, if necessary, to the discussion of the reaction of paraffin hydrocarbons with bromine and chlorine.

In conclusion, another typical reaction of olefinic hydrocarbons is polymerization. Because of unsaturation it becomes possible for molecules to add to one another and build up hydrocarbons of high molecular weight. One of the newer polymeric substances which is finding a variety of uses is polyethylene or polythene, prepared from ethylene. Polymorpylene is a similar nolymer.

## The Acetylene Series of Hydrocarbons

The hydrocarbons of this series, like those of the ethylene series, are unsaturated. However, the degree of unsaturation is higher, and it is represented by a triple bond between adjacent carbons. The triple bond becomes a simple way of representing three pairs of shared electrons. The data of the accompanying table and the

THE	ACETYL	ENE	SERIES

structures given illustrate a number of the acetylenic hydrocarbons. All conform to the type formula  $C_0H_{2n-2}$ .

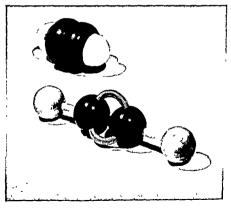


Fig 7—Models of the Acetylene Molecule. How many atoms of hydrogen can be added to one molecule of acetylene<sup>2</sup> Courtesy, Tobias Studio, Akron, Ohio

In scientific nomenclature the hydrocarbons of the acetylene series are called *alkynes*. By far the most important hydrocarbon of this series is acetylene itself. Acetylene does not occur in nature, but it can be made very easily from calcium carbide and water at room conditions.

$$CaC_2 + 2 H_2O \rightarrow C_2H_2 + Ca(OH)_2$$

Acetylene gas with air forms highly explosive mixtures, and care must be used in preparing and using this hydrocarbon.

The acetylenic hydrocarbons, in a general way, exhibit the same reactions as the olefins, this is to be expected because both types are unsaturated. Inasmuch as the degree of unsaturation is higher in the acetylenes it is necessary for them to add on greater amounts of hydrogen, chlorine, etc., before becoming saturated. The ethylene molecule, as we have seen, becomes saturated by adding on one molecule (two atoms) of bromine. To saturate the acetylene molecule two molecules of bromine are required.

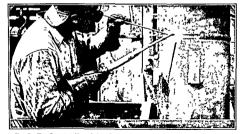


Fig. B—The Greatest Use of Acetylene, The oxysoctylene flame, produced by burning acetylene in pure oxygen, is a source of intense heat (3300 ± °C), and is used in welding, cutting, and melting metals or their allays. What elementary substance, previously studied, burns in oxygen to provide a similar high temperature flame? Courtery, Linde Co.

By self addition, or addition to similar molecules, acetylenic hydrocarbons form higher molecular weight products. Acetylene, for example, is a starting material for the preparation of neoprene, a high molecular weight polymer which has rubber-like properties.

# Three Typical Aliphatic Hydrocarbons:

Inasmuch as methane, ethylene, and acetylene are very important and also representative members of their respective series, some further facts about them are included in the table which follows

THREE IMPORTANT ALIPHATIC HYDROCAPRONS

Hydrocarbon	Physical State	Properties and Uses	
Methane CH4	Gas	Combustible. Known also as marsh gas and fire damp Occurs in natural gas Valuable as a fuel and for the prepa- ration of gas black (lamp black) A constituent of intestinal gases from decomposition of food residies	
Ethylene CH <sub>2</sub> =CH <sub>2</sub>	Gus	Combustible Mized with oxygen, ethylene is a useful anesthetic Mixed with sir, in low concentration, ethylene is used to change the color of green fruits, for example, citrus fruits, to the color of ripe fruit.	
Acetylene CH = CH	Gas	Highly explosive with air. When prop- erly burned gives a brilliant white light and intense heat Used with oxygen in the oxyacetylene torch Raw material for synthesis of many organic compounds	

# The Cycloparaffins. Cyclopropane:

The cycloparaffins are ring structures, and inasmuch as the members of the series are saturated their chemistry is in many respects similar to that of the aliphatic paraffins. The structures for two typical members of this series are presented here.

Cyclopropane, a colorless gas, is of particular importance because of its use as an inhalation anesthetic. When thus employed it is mixed with oxygen. The chief disadvantage in its use as an anethetic is its explosive character. It has the advantage of being nonirritating, and recovery is rapid with no ill after effects



Fig. 9.—An Anesthetic. Cyclopropane  $\{C_3H_6\}$  or trimethylene made its first clinical appearance in 1933 at the University of Wisconsin

Before dismissing the cyclic aliphatic hydrocarbons it is to be pointed out that there are also cyclo olefins. These are cyclic hydrocarbons in which a double bond appears between adjacent carbon atoms. Cyclohexene,  $C_0H_{10}$ , is one of the best known hydrocarbons of this type

### The Aromatic Hydrocarbons Benzener

All of the aromatic hydrocarbons and their many derivatives exhibit a type of structure known as the benzene or aromatic ring The simplest and most important hydrocarbon of the aromatic division is benzene

The aromatic ring, as depicted in the structure of benzene itself. consists of six carbon atoms with single and double bonds placed in alternate positions around the ring. Such an arrangement of bonds makes each carbon tetravalent. The presence of the double bonds implies that considerable unsaturation should exist. However, the unsaturation of the aromatic ring is of an unusual type. and ordinarily the replacement of the hydrogens, which is substitution, is much more readily accomplished than is addition to the double bonds. Later there will be occasion to consider some of the derivatives of benzene, and it will be found that these are the result of replacing one or more of the hydrogens of benzene with other atoms or radicals

Benzene is a colorless liquid of characteristic odor. One of the most important sources of this hydrocarbon is coal tar, a liquid obtained as a by-product in the preparation of coke by the destructive distillation of soft coal. Benzene has great value as the starting material for the preparation of a large number of synthetic aromatic compounds.

### SELF-TESTING QUESTIONS

- 13 What are the names of the various series of hydrocarbons?
- 14 What is the important structural difference between the saturated and the unsaturated hydrocarbons?
- 15 Why is it impossible for an alkane to form addition products? 16 To what series of aliphatic hydrocarbons would C12H22 belong?
- 17 What are homologues? What are isomers? Illustrate 18 What is polymerization? Why cannot the alkanes show this type of
- reaction?
- 19 In what respects is cyclopropane like propane? How do they differ?
- 20 How is it possible to have five different hydrocarbons, all of formula CoH14? Illustrate by giving suitable formulas

- 21 What chemical property is characteristic of all hydrocarbons, regardless of structure?
- 22 How does the substitution type of reaction differ from the addition type?
- 23 How many products are formed in a substitution reaction? How many are formed in the addition reaction?
- 24 How is acetylene prepared? Write the equation for its combustion
- 25 What is a structural characteristic of all aromatic compounds?
- 26 How does the unsaturation pictured by the benzene ring compare with the unsaturation of ethylene and other olefins?

### IV. HALOGEN DERIVATIVES

## Some Common Halogen Substitution Products:

There are a number of halogen derivatives of the hydrocarbons which because of their uses merit consideration at this point. Several have already been mentioned in this chapter in connection with the reactions of the hydrocarbons. The table (page 278) gives the names, structures, and other pertinent data







Fg 11—Local or General Anesthesia Ethyl chloride Used in minor surg ery What is the appearance of the skin when frozen?

The first four compounds in the table can be looked upon as derivatives of the hydrocarbon methane Ethyl chloride is structurally related to ethane, and trichloroethylene is derived structurally from ethylene

## SOME HALOGEN DERIVATIVES OF HYDROCARBONS

Name	Structure	Physical State	Uses
Chloroform	CI CI CI I	Colorless liquid	Anesthetic Solvent for fats and oils
Carbon tetrachloride	CI CI CI	Colorless liquid	Solvent for fats and oils Fire extinguisher
Iodoform	H I—C—I	Yellow solid	Mild antiseptic activ ity due to slow liber ation of iodine
Dichloro difluoromethane (freon)	Cl-C-Cl	Gas (easily compressed to liquid)	Refrigerant in house hold refrigerators and air conditioners
Ethyl chloride	H H H-C-C-CI H H	Gas (easily liquefied)	Local anesthetic rapid evaporation freezes tissue Inhalation anesthetic
Trichloroethylene	CI-C-C-CI	Liquid	Industrial solvent Used in preparations for cleaning clothes ruga etc

## SELF-TESTING QUESTIONS

- 27 Which halogen derivatives of hydrocarbons have use as anesthetics? Which are useful solvents?
- 28 What are the four chlorine substitution products derived from methane?
- 29 How would you make ethylene d chloride from ethylene?
- 30 In what type of fire extinguisher is carbon tetrachloride found?

Note The remainder of this chapter may be amitted when I me must be saved

### V. PETROLEUM, A LIQUID SECOND IN IMPORTANCE TO WATER

Whenever organic material decomposes in the presence of air, most of the carbon unites with oxygen to form carbon dioxide,

but in the absence of air, the carbon is left combined with hydrogen to form the hydrocarbons. They furnish the logical starting point for the study of organic compounds. The commercial importance of these hydrocarbons may be appreciated when we learn that they make up such valuable substances as natural gas, gasoline, kerosene, lubricating oils, petroleum jelly, and paraffin.

# Composition of Petroleum:

Most hydrocarbons come from petroleum, which includes both crude oil and natural gas and is found only in porous rocks, usually of sedimentary origin. The porous rocks, such as sand stone, act as reservoirs for gases and liquids. Gas being the lightest tends to accumulate in the top of the reservoir, while the oil which is lighter than water will in time separate and accumulate above the water. Oil and gas are usually found together, but may occur separately. Although petroleum is widely distributed over the world, the largest part (70 per cent) is obtained in the United States (Fig. 12).

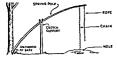
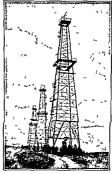


Fig. 12 (Above)—The first wells dug in this country were for salt), and the "spring pole" method employed was adopted in many early oil wells. This consisted of a limber pole, anchored at one end, and passed over a post. Men polled at the rope at the far end, causing the pole to spring and driving the drilling fools against the bottom of the hole. The method was originated by the Chinese 2,000-odd years ago Now drilling methods are of two types—Cable Tool (percussion) in hard rock formations and the more commonly used Ratary Method.



(Right)—Giant oil derricks pumping oil, the life blood of the machine age. Petroleum oils are complex mixtures of hydrocarbons, containing sulfur, nitragen, and oxygen derivatives. Why is it necessary to remove sulfur compounds from gasoline derived from petroleum? Courtery, H., Armstrong Roberts, Philadelphia.

When this supply becomes exhausted the oil bearing shales of Utah and elsewhere promise to furnish even greater yields of petroleum than now available Petroleum is of industrial importance chiefly as a source of fuel, of lubricants, and to some extent as a source of solvents. The oil industry has provided the lifeblood of victory in two world wars and has built the United States into a nation on wheels in time of peace

All petroleum oils are not alike, they contain different kinds of hydrocarbon mixtures, as a result of the decomposition of different varieties of plant life, under different conditions of temperature and pressure Some oils even point to animal origin All contain a varying amount of ill smelling sulfur compounds, which make them objectionable for most commercial uses. In buying automobile oil and gasoline we hear continual reference made to oils of a paraffin or of an asphalit base. Pennsylvania oil has a paraffin base and makes a fine grade of lubricating oil. On the other hand, our petroleum oils of the West (California) are mostly of an asphalitum base and are supposed to give an excellent grade of gasoline, but not such good lubricating oils, however, in the light of present refining methods it is difficult to draw much distinction between these two kinds of oils.

## Refining of Petroleum

Some crude oil is used for fuel but the greater part is subjected to fractional distillation, a process whereby different portions boiling at different temperatures are collected separately. The separation, as usually carried out, attempts to produce three main products gasoline, kerosene, and lubricating oils. In some cases the distillation is stopped at a certain temperature so that there will be left



Fig 13—A Drum of Hydrocarbons. Volume of products obtained from a barrel of crude petroleum. To what extent may these percentages vary?

a residue of asphalt. At other times the distillation is carried on until nothing is left but petroleum coke. Some varieties of petroleum yield, in addition to lubricating oils, a black pitch used in roofing and painting.

The next step in the refining is to remove from the distillates the objectionable materials, such as the foul smelling sulfur compounds and the waxy or tarry substances which oxidize on exposure to air to form gummy products that interfere with burners or carburetors. This is accomplished by agitating the distillate with sulfuric acid, removing the charred material and spent sulfuric acid, carefully neutralizing any remaining acid with a base, and then washing with water to remove all remaining impurities.

The first oil distillate may be refined by being filtered through bone black, which removes the color and improves the odor and taste. In this refined state it is used in medicine to prevent constipation and is commonly called albolene or mneral oil. From a chemical standpoint the mineral oils have no relation to the animal and vegetable oils in that the mineral oils are not digested or absorbed, but merely act as lubricants.

Since gasoline is the most valuable product of the refining process, the yield of "straight run" gasoline, obtained by distillation of the more volatile hydrocarbons (heptane, octane) has been materially increased (about 50 per cent) by decomposing the heavier molecules of oils into lighter molecules by means of heat and pressure. This cracking process produces a large amount of unsaturated aliphatic hydrocarbons, frequently called olefins.

The following table throws some light on the physical properties and uses of the commercial products obtained from petroleum:

Name	Specific Gravity	Boiling Point	Uses
Petroleum ether	 0 65 to 0 67	35° to 80°	Solvent
Gasoline	0 73 to 0 76	40° to 223°	Fuel
Naphtha	0 66 to 0 80	40° to 225°	Solvent
Kerosene	0 80 to 0 84	175° to 300°	Light, fuel
Lubricating oils	 0 86 to 0 95	350° up	Lubrication
Paraffin	0 90 to 0 93	50° to 60° M P.	Candles, wax
Asphalts	0 93 to 1 10	Viscous liquids to 150° M P.	Paving, roofing
Coke .			Fuel

### SELF-TESTING QUESTIONS

- 31 What promises to be our greatest natural source of petroleum in the future?
- 32 What is the general difference in composition properties between the oils of Pennsylvania and California?
- 33 What is fractional distillation?
- 34 How do petroleums differ in their distillates and residues?
- 35 How are impurities removed from gasoline? from oil?
- 36 What is meant by the 'cracking of oils"?

### SUGGESTED ACTIVITIES

- I THOUGHT-PROVOKING QUESTIONS
  - 1 How did the work of Wohler aid in our understanding of the normal processes of the body?
    - 2 Besides the five general ways mentioned, in what other ways do organic compounds differ from inorganic?
      - 3 How has organic chemistry been of aid to the physician?
    - 4 What is the meaning of structural, empirical, and molecular formulas?
    - 5 Make the structural formula of ethyl alcohol, C2H5OH, and explain why this compound is inactive in solution
    - 6 Write graphic formulas showing that carbon may act as a metal or a nonmetal.
    - 7 Enumerate all of the reasons for the formation of isomeric com
    - 8 In addition to the satisfaction of acquiring knowledge what im portance is attached to the study of organic chemistry?
    - 9 What is the ultimate source of most of the carbon in plant products? 10 Considering that fuel gases consist of various hydrocarbons such as methane, ethylene, and acetylene, write equations to show how an madequate supply of oxygen might account for soot
    - (carbon) deposits on utensils over these burning fuels 11 Lubrication of rubber equipment with mineral oil or petroleum jelly tends to dissolve the rubber. What does this solubility show concerning the structure of rubber?
- II VOCABULARY TESTING OF NEW TERMS

organic chemistry biological chemistry hydrocarbons homologous series

saturated compounds substitution products unsaturated compounds isomenc

aliphatic aromatic heterocyclic carboevelie

- III TOPICS FOR ORAL OR WRITTEN REPORTS
  - 1 Living Organisms Are Chemical Laboratories 2 Why Coal Tar Has Become a Valuable By product
    - 2 Organic Chemistry in the Service of Medicine
    - 4 Some Recent Advances in Medicine Made Possible by Organic Compounds

## LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on pages 701, 704, 708

### CHAPTER XIII

# THE ALCOHOLS, ALDEHYDES, KETONES, AND ETHERS

### CHAPTER OUTLINE

I THE ALCOHOLS

(a) Nature of alcohols

- (b) The series of saturated mono hydric alcohols
- (c) Isomerism (d) Classification of alcohola
- (e) The oxidation of alcohols
- (f) Other reactions of alcohols (g) Two important monohydric
- alcohols (h) Polyhydric alcohols
- II. THE ALDERYDES
- (a) Nature of aldehydes

- (b) The oxidation of aldehydes (c) Polymers from aldehydes (d) Two important aldehydes
- III THE KETONES
  - (a) The structure and nature of ketones
    - (b) An important ketone

IV THE ETHERS

- (a) Nature of ethers (b) Preparation and properties of ethyl ether
- (c) Anesthetics

### Introduction:

With some understanding of the hydrocarbons we can now consider some series of compounds which contain elements in addition to carbon and hydrogen. We pass from the study of the fundamental hydrocarbons to organic compounds called derivatives. These are compounds which are formed by substituting atoms or radicals for an equivalent number of hydrogens in the hydrocarbon.

An element often found in derivatives of hydrocarbons is oxygen. There are three general groups of these compounds of carbon, hydrogen, and oxygen, namely, (1) the alcohols, which may be viewed as first oxidation derivatives of hydrocarbons, (2) the aldehydes and ketones, the second oxidation derivatives, and (3) the carboxylic acids, the third oxidation derivatives. Structurally related to these general groups of oxygen-containing compounds are the ethers and esters, and the carbohydrates and fats.

### I. THE ALCOHOLS

## Nature of Alcohols:

The general public knows two alcohols. These are grain alcohol, which is present in alcoholic beverages, and wood alcohol, a highly poisonous substance. In this chapter we shall find that there are many other alcohols, and that all have a similarity of structure.

The alcohols may be considered as derived from the hydro carbons, at least structurally, and all of them contain in addition to carbon and hydrogen a third element, oxygen. The characteristic group in which the oxygen appears is the —OH structure. When this is found in the inorganic compounds it is customarily called the hydroxyl radical, and the compounds are classified as bases. We have learned that the water soluble bases provide solutions containing hydroxyl ions, OH—Alcohols, however, are not bases. They are neutral substances and they do not discocate in water Therefore somewhat different properties are typical of the —OH radical when it is present in organic molecules, and one must think of it as the alcohol group.

Organic chemists frequently use R to denote the various hydro carbon radicals, for example methyl, ethyl, and n propyl On this basis one can set up a general formula for the alcohols. This formula is R—OH, and it points out that in its simplest form the alcohol consists of a hydrocarbon radical linked to an alcohol group, i.e., the —OH group

Actually some alcohols contain more than one alcohol group in the molecule. Those containing but one are classified as mono hydric, those with two are dihydric, three trihydric etc. Methyl alcohol, CH<sub>2</sub>(OH)<sub>2</sub> is a monohydric alcohol ethylene glycol, C<sub>2</sub>H<sub>1</sub>(OH)<sub>2</sub> is a dihydric alcohol, and glycerol, C<sub>2</sub>H<sub>2</sub>(OH)<sub>3</sub> is thrihydric. However, since we are primarily interested in the chem istry of the alcohol group, most of the discussion presented here will be based on the monohydric alcohols.

## The Series of Saturated Monohydric Alcohols

The accompanying table gives the names and formulas for the first several members in the series of monohydric alcohols. All

### MONOHYDRIC ALCOHOLS

Name	Formula	Possible Structures
Methyl alcohol	CH <sub>2</sub> OH	1
Ethyl alcohol	C <sub>2</sub> H <sub>5</sub> OH	1
Propyl alcohols	CaH2OH	2
Butyl alcohols	C <sub>4</sub> H <sub>9</sub> OH	4
Amyl alcohols	C <sub>4</sub> H <sub>11</sub> OH	8
Hexyl alcohols etc	C <sub>5</sub> H <sub>13</sub> OH	17

carbon to carbon bonds are single linkages, and therefore these are saturated alcohols

An inspection of this list of alcohols shows that the series is a homologous one, that is, consecutive members differ in formula by the unit —CH<sub>2</sub>— Also, using n to denote the number of carbon atoms in the molecule, the general formula for all members of this series becomes C<sub>2</sub>H<sub>2-2+1</sub>OH

Methyl alcohol, ethyl alcohol, and the propyl alcohols are soluble in water in all proportions Starting with the butyl alcohols the solubility in water falls off rapidly The lower members of the series are liquids, and possess rather pleasant odors Higher members are solids For example, lauryl alcohol,  $\mathrm{CH_3(CH_2)_{10}CH_2OH}$ , is a white, water-insoluble solid

### Isomerism:

Reference to the table shows that beyond ethyl alcohol the type of formula given is not adequate. There are two different propyl alcohols,  $C_4H$  OH, and four different butyl alcohols,  $C_4H_9\mathrm{OH}$  Just as was learned in the study of the hydrocarbons, when two or more substances have the same molecular formula one must make use of structural formulas to show how the isomers differ Following are the expanded and also the condensed structural formulas for the alcohols of this series through the butyl alcohols

In examining the structures observe how one makes use of the names for the hydrocarbon radicals in naming alcohols

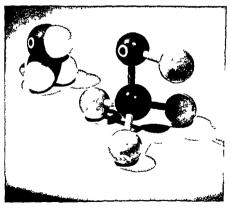


Fig 1—Models of the Methyl Alcohol Molecule. The model on the right is the boll and stick type, and the one on the left is a scale model. The small white cardle identifies the oxygen atom. What grouping is distinctive in all alcohols? Courtery, Tobias Studio, Akton, Ohio.

#### A Classification of Alcohols:

An important classification of alcohols is made possible on the basis of the position of the alcohol group relative to the remainder of the molecule. In this classification alcohols are designated as primary, secondary, or tertiary. In all primary alcohols, excepting methyl alcohol, the carbon atom to which the alcohol group is joined has attached to it two hydrogen atoms. In the case of methyl alcohol, the simplest of all primary alcohols, the number of attached hydrogens is three. For all secondary alcohols the carbon atom which carries the alcohol group has but one hydrogen directly attached to it, and in the tertiary alcohols the carbon atom carrying the alcohol group has no hydrogens attached. The general formulas for the three classes then become

In all cases, excepting methyl alcohol, R, R' and R" denote hydro carbon radicals Now look back to the section preceding this one and classify each of the eight alcohols as primary, secondary, or tertiary

This classification becomes important in a study of the alcohols because each type shows in some respects a different chemical behavior from the others. We shall see this now as we turn to a study of the oxidation of alcohols.

### The Oxidation of Alcohols:

Alcohols burn to produce carbon dioxide and water when the combustion is a complete one Ethyl alcohol, for example, burns with a hot, blue flame, and becomes a suitable fuel for alcohol burners and heat lamps

$$C_2H_5OH + 3 O_2 \rightarrow 2 CO_2 + 3 H_2O + energy$$

This equation represents a complete high temperature oxidation.

Through the use of aqueous oxidizing agents a number of im

Through the use of aqueous oxidizing agents a number of important classes of organic compounds can be prepared from the alcohols, these are intermediate between the alcohols themselves and the products of their complete oxidation which we have just seen to be carbon dioxide and water. In this connection the classification as primary, secondary, and tertiary becomes important inasmuch as each type shows a different behavior when oxidized

For this kind of oxidation some of the suitable oxidizing agents are potassium permanganate solution, sodium or potassium di chromate solution acidified with sulfuric acid, dute intire acid, etc. When ethyl alcohol is treated with neutral potassium per manganate solution the first oxidation product is an aldehyde, CHaCHO. Called acetaldehyde.

3 C<sub>2</sub>H<sub>2</sub>OH 
$$+$$
 2 KMnO<sub>4</sub>  $\rightarrow$  3 CH<sub>3</sub>CHO  $+$  2 KOH  $+$  2 MnO<sub>2</sub>  $+$  2 H<sub>2</sub>O

Ethyl gloshol

Acetaldehyde

Balanced equations of this type are time consuming to write In studying the oxidation of alcohols and, on occasion other substances we shall therefore indicate the use of a suitable oxidizing agent like those just mentioned, by writing an O, the symbol for oxygen above the arrow in the equation. In this way the balanced equation which has just been given is greatly simplified.

The aldehydes like the primary alcohols from which they are formed, are easily oxidized Hence, if some provision is not made for promptly removing aldehydes from the presence of the oxidizing agent, they are oxidized to carboxylic acids Acetaldehyde gives acetic acid

Methyl alcohol is the simplest of all of the primary alcohols and the stages in its oxidation are as follows

Unlike the other organic acids of its type, formic acid is readily oxidized by aqueous oxidizers to give carbon dioxide and water

Notice that the number of hydrogens attached directly to the carbon which originally carried the alcohol group decreases from two to none in the oxidation of ethyl alcohol and from three to none (in  $CO_2$ ) in the oxidation of methyl alcohol

Generalized formulas are helpful in depicting the oxidation of the primary alcohol

To summarize, the oxidation of a primary alcohol by the use of suitable oxidizing agents produces first the aldehyde. The aldehyde in turn is readily oxidized to the carboxylic acid. In the case of formic acid the oxidation may continue to give carbon dioxide and water. The homologues of formic acid are sufficiently resistant to oxidation to be unaffected. Also, in the study of the behavior of primary alcohols with aqueous oxidizers two new types of organic compounds have been met with, namely, the aldehyde and the carboxylic acid.

The oxidation of secondary alcohols with aqueous oxidizers follows a different course from primary alcohols. The simplest secondary alcohol is isopropyl alcohol, its oxidation produces acetone, a compound which is classified as a ketone

The ketones are not easily oxidized More powerful oxidizers than those considered here will attack ketones, but in so doing deep seated decomposition sets in with the formation of products having fewer carbon atoms in the molecule. Notice in the secondary alcohols that the carbon atom to which the alcohol group is attached carries but one hydrogen, and this is removed in forming the ketone

The use of general formulas leads to the following equation

As a summary, the oxidation of a secondary alcohol produces a ketone Ketones in turn resist oxidation

Molecules of tertiary alcohols have no hydrogen attached to the carbon atom which carries the alcohol group Tertiary alcohols are consequently resistant to oxidation. Powerful oxidizers break them down into molecules which contain a fewer number of carbon atoms than the tertiary alcohols is tertiary but of the tertiary alcohols is tertiary butyl alcohol.

#### Other Reactions of Alcohols:

In some alcohols, particularly the primary ones, the hydrogen of the alcohol radical can be replaced by very active metals

Alcohols react with acids, both morganic and organic, to produce "ethereal salts," more commonly called esters. Nitrous acid reacts with n amyl alcohol to give the ester n amyl nitrite. This compound has use in medicine as a vasodilator in angina pectoris. Since it relaxes bronchial muscles, n amyl nitrite is useful in treating asthma.

The sulfuric acid ester of lauryl alcohol is of interest because its sodium salt is an important detergent. The steps in its manufacture are as follows

Sodium lauryl sulfate and similar compounds are widely used as soapless detergents

The behavior of alcohols with organic acids will be considered later after the carboxylic acids have been studied

Alcohols are starting materials for the preparation of ethers. In a later section of this chapter it will be shown how ethyl ether is manufactured from ethyl alcohol

In addition to the reactions of the alcohols which have been discussed here there are many others. A number of the alcohols are cheap, readily available compounds, and they are sufficiently reactive to serve as raw materials for synthesizing a variety of more complex organic compounds.

# Two Important Monohydric Alcohols

Methyl alcohol and ethyl alcohol are of sufficient importance to warrant individual attention

The scientific name for methyl alcohol is methanol, and this has come into rather general usage. Methyl alcohol is also known as wood alcohol because at one time an important source was a liquid called pyroligneous acid which is produced in the destructive distillation of wood. Today the important source is synthesis from carbon monoxide and hydrogen. These gases are mixed in proper proportions and heated at 400° C. and 150 atmospheres of pressure in the presence of a catalyst.

Methyl alcohol is a colorless liquid which boils at 65° C. It is miscible with water in all proportions The vapors of this alcohol burn readily with a hot blue flame. Methanol is highly poisonous. In the body it is oxidized to toxic formic acid which will paralyze the optic nerves and lead to blindness. Death may ensue from farger amounts; two to four ounces are usually fattle.

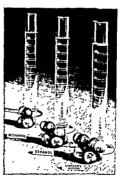


Fig. 2.—Three Important Alcohols. The models show the molecular structure of these three alcohols. The dihydric alcohols, called ethylene glycol, is an excellent antifreeze solution for automobile radiators. Why is it better for this purpose than the other two alcohold? Courtery, Carbide and Carbon Chemicals Capy.

Despite its poisonous nature large quantities of methyl alcohol are produced to supply industrial demands. In the field of paints and varnishes it is a solvent for shellacs and resins. Considerable quantities are used as antifreeze.

Ethyl alcohol is produced by fermentation of sugars which in turn frequently come from the hydrolysis of starch Barley and com have long been used to supply starch for this purpose. This has resulted in the name grain alcohol for ethyl alcohol. Thus, glucose sugar in the presence of yeast which supplies the enzyme called zymase is fermented to give ethyl alcohol and carbon dioxide

Glucose can be obtained by hydrolyzing most varieties of starch Much of the industrial ethyl alcohol produced in this country comes from fermentation of the sugars present in molasses, the latter a by product from the refining of sugar

Another important present day source of ethyl alcohol is its synthesis from ethylene CH<sub>2</sub>-CH<sub>2</sub>, an unsaturated hydrocarbon which is formed in the cracking of petroleum oil. Notice that the molecular formulas for ethylene and ethyl alcohol differ by H<sub>2</sub>O Ethylene does not add water directly to give ethyl alcohol, yet chemists have learned how to accomplish this indirectly, and very efficiently

In scientific nomenclature ethyl alcohol is called ethanol This alcohol is a colorless liquid which boils at 78° C, and like methyl alcohol it is soluble in water in all proportions

Ethanol is the alcohol which is present in alcoholic beverages in these the per cent of alcohol by volume ranges from 3 to 4 per cent in beer to as high as 55 per cent in whisky and brandy. In the body, ethyl alcohol is quickly absorbed without digestion and then oxidized to carbon dioxide and water with the production of seven Calories of heat energy for each gram of alcohol. While controlled amounts of ethyl alcohol are valuable medicinally as a stimulant in conditions of shock and collapse, it is a scientific fact that excessive use of alcoholic beverages has highly undesirable effects Initially it produces an increase in respiration and a rise in blood pressure, but shortly there follows a drop below normal. Taken internally in large amounts ethyl alcohol causes impairment of mental processes and a loss of muscular coordination. Any indi-

vidual in such a state who is driving an automobile becomes a potential killer. It is well known that continued unrestricted use of ethyl alcohol leads to chromic alcoholism

#### ETHYL ALCOHOL IN BEVERAGES

Distilled (40 to 60 per cent Alcohol)	Undistilled (3 to 10 per cent Alcohol)	
Brandy from wine Whiskey* from fermented malt solution	Beer from fermented malt and hops  Ale from fermented malt and hops	
Rum from fermented molasses	Wine from fermented fruit juice	
Gin from whiskey flavored with jumper	Added alcohol makes fortified wines as port (15 18%) and sherry (18-21%)	

<sup>\*</sup> Whiskey is a dutillate obtained from grains that have been ground into meal mixed with water and malted grains cooked to a meah yeast added and then fermented for 72 hours

Ethanol in 50 to 70 per cent concentration is a disinfectant widely used in hospitals for surface application. It destroys organisms by coagulating protoplasm. Preparations known as tinctures and spirits contain this alcohol as the solvent. Denatured alcohol is made by adding to ethanol small quantities of substances which render it unsuitable for drinking. Certain types of denatured alcohol are used externally as rubbing liquids however, isopropyl alcohol has been supplanting ethyl alcohol for this use.

Second to water, ethanol is the most widely used of all solvents It is also an important starting material for manufacturing other organic compounds

# Polyhydric Alcohols

Compounds which have two alcohol groups in their molecules are known as glycols. The simplest and most important of these is ethylene glycol, which is a primary alcohol twice over It has a relatively high boiling point of 197° C and is soluble in water in all proportions. Ethylene glycol has wide usage as a permanent antifreeze for automobile radiators and is sold for this purpose under such trade names as Prestone and Zerex. Ethylene is the starting material for the preparation of this dihydric alcohol

Glycerol is a trihydric alcohol as evidenced by its structural formula Important sources of glycerol are the animal and vege table fats and oils In the manufacture of soap these natural fats and oils are sapomfied, and glycerol appears as a by-product More recently, methods have been perfected for synthesizing glycerol from propylene, CH<sub>2</sub>—CH=CH<sub>2</sub>

Glycerol is a clear viscous liquid of sweet taste. It is hygroscopic and soluble in water. Since glycerol is nontoxic it may be used as a solvent in the preparation of certain medicines, and its nontoxic character coupled with the fact that it is hygroscopic accounts for its wide usage in lotions and other cosmetics. Nitroglycerine, one of the important explosives, is made by reacting glycerol with nitric acid. Inasmuch as this substance is an ester of glycerol it is more correctly called glyceryl trimitrate. Dynamite contains glyceryl truntrate

#### SELF-TESTING QUESTIONS

- Name four fundamental types of organic compounds which contain carbon hydrogen and oxygen
- 2 What is an alcohol?
- 3 How are the saturated monohydric alcohols classified?
- 4 What is produced when the primary alcohol is oxidized with an aqueous oxidizer? What is formed from the secondary alcohol?
- 5 In what chemical characteristic does the tertiary alcohol differ from the primary and the secondary?
- 6 Compare and contrast the physical properties of the lower and the higher alcohols
- 7 What is the physiological effect of small amounts of grain alcohol? of large amounts?
- 8 Why is methyl alcohol more poisonous than ethyl alcohol?
- 9 What are glycols? What is the simplest one?
- 10 Are alcohols bases? How does the alcohol differ from the morganic base?

- 11 What is the nature of a homologous series of compounds?
- 12 Which is correct in Propyl and isopropyl alcohols are isomers or are homologues?
- 13 What is the most important source of industrial methyl alcohol?
- 14 What two methods of preparation provide industrial ethyl alcohol?
  15 Why is glycerol an important ingredient in many brands of hand lotion?

# II. THE ALDEHYDES

### Nature of Aldehydes:

We have learned that the aldehydes are the first oxidation products of the primary alcohols, and this is an important method for their preparation. The following table gives the first few members in the homologous series of aldehydes.

#### ALDEHYDES

Name	Formula	Number of Structures
Formaldehyde	нсно	1
Acetaldehyde	CH <sub>3</sub> CHO	1
Propionaldehyde	CH₄CH₂CHO	1
Butyraldehydes etc	C <sub>3</sub> H <sub>7</sub> CHO	2

H

All aldehydes possess the —C=0 structure, commonly known as the aldehyde group The general formula for the aldehydes becomes H

R—C=O, where R is hydrogen in the case of formaldehyde, but a hydrocarbon radical for all others. Notice that two butyraldehydes exist, one is called n-butyraldehyde and its isomer is known as isobutyraldehyde. It is suggested that the reader write the structural formulas for these two compounds

### The Oxidation of Aldehydes:

In discussing the oxidation of primary alcohols it was shown that aldehydes are easily oxidized to give carboxylic acids, hence, aldehydes are reducing agents

Aldehydes will reduce cupric ion  $(Cu^{++})$  to cuprous ion  $(Cu^{+})$  Fehling's solution and Benedict's solution both provide cupric copper, in the form of cupric hydroxide, for this kind of reaction Ordinarily cupric hydroxide is insoluble, but the solutions just named contain tartrates and citrates which are effective in preventing the separation of  $Cu(OH)_2$ . The behavior of either one of these solutions is shown in the following equation

Both Fehling's and Benedict's solutions have a clear blue color. A positive test is recognized by the formation of insoluble cuprous oxide, red in color. Notice that as the aldehyde is oxidized to the acid the cupric copper in the reagent is reduced in valence from  $\pm 2$  to  $\pm 1$  in Cu<sub>2</sub>O. Fehling's reagent is prepared as two separate solutions to be mixed just before use. Benedict's reagent is a single solution, hence more convenient to use, and this fact together with its somewhat greater sensitivity makes it the preferred reagent.

The sugar glucose (blood sugar) contains an aldehyde group and therefore gives a positive response with Fehling's and Benedict's solutions This provides a simple rapid clinical test for blood sugar in the urine

Similarly, aldehydes will reduce silver ions to metallic silver Tollen's reagent contains a compound of silver which provides silver ions for this type of test. The following equation expresses the essentials of this reaction

By proper techniques the silver metal can be deposited on the sides of the container as a silver mirror

The above reactions may be used to differentiate aldehydes from

ketones The ketones are sufficiently resistant to oxidation to be unaffected by these reagents

### Polymers from Aldehydes

In addition to being excellent organic reducing agents the alde hydre form polymers. When a water solution of formaldehyde is treated with a trace of sulfuric acid and then evaporated to dryness a solid residue appears. The solid is a polymer of the aldehyde which contains from ten to as many as one hundred molecules linked together into one large molecule. It is known as paraformal dehyde, and since it releases formaldehyde vapors when heated it is used in the form of candles and in lamps for disinfecting purposes. There are also other polymers of formaldehyde.

Acetaldehyde under the catalytic influence of sulfuric acid polymerizes to a liquid called paraldehyde. This substance is constructed from three molecules of the aldehyde and is designated by the formula (CH<sub>3</sub>CHO)<sub>3</sub> Paraldehyde has medicinal value as a soporific

Polymerization is not confined to the two aldehydes just considered, but rather it is a general behavior of this class of compounds

### Two Important Aldehydes

Formaldehyde and acetaldehyde the first two members in the series of saturated aliphatic aldehydes are sufficiently important to be discussed further

Formaldehyde can be prepared by the controlled oxidation of methyl alcohol At room conditions this aldehyde is a gas which possesses a sharp penetrating odor The water solution which con tains 37 to 40 per cent of formaldehyde is known as formalin This solution hardens tissue by coagulating the protein and for this reason it is used as a preservative for biological specimens

The reaction of formaldehyde with ammona gives a solid compound called urotropine,  $(CH_2)_8N_4$  Urotropine is stable in the presence of alkalies, but it decomposes in acid media to produce formaldehyde. For many years it has been an important urmary antiseptic, but recently sulfa drugs have to some extent replaced it

Acetaldehyde is the first oxidation product from ethyl alcohol Another source is synthesis from acetylene Acetaldehyde is a liquid of sharp odor which boils at 21° C, just slightly below usual room temperature

Chlorine reacts with acetaldehyde in a substitution type of re

action to give chloral, an oily liquid With water, chloral forms a white solid, chloral hydrate This substance is a powerful hypnotic, added to alcoholic beverages it constitutes the so called knockout drops

#### SELF-TESTING QUESTIONS

- 16 What are the steps in the oxidation of the primary alcohol?
- 17 What characteristic group is found in all aldehydes?
- 18 Why is the Benedict test of clinical importance?
- 19 How is it possible to distinguish between aldehydes and ketones?
- 20 What are the properties and uses of formaldehyde?
- 21 What are the properties and uses of acetaldehyde?
- What is produced when an aldehyde is oxidized?
   What is an important substitution product of acetaldehyde? For what
- is it used?

  24 In what way is formaldehyde related to paraformaldehyde?
- 25 Embalming fluids contain formaldehyde Why is this?

### III. THE KETONES

### The Structure and Nature of Ketones:

The ketones are oxidation products of the secondary alcohols and conform to the type formula R-C-R' Several of the first

members in the series are given in the table. Notice that the ketones are commonly named by designating the two hydrocarbon radicals

which are attached to the C=0 group, known as the carbonyl

#### KETONES

Name	Condensed Structural Formul	
Dimethyl ketone Methyl ethyl ketone Diethyl ketone Methyl n propyl ketone Methyl isopropyl ketone etc	CH <sub>3</sub> COCH <sub>3</sub> CH <sub>2</sub> COC <sub>2</sub> H <sub>3</sub> C <sub>2</sub> H <sub>3</sub> COC <sub>2</sub> H <sub>5</sub> CH <sub>3</sub> COCH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub> CH <sub>3</sub> COCH(CH <sub>3</sub> ) <sub>2</sub>	

group This same group is found also in the aldehydes, where at least one of the attached factors must be a hydrogen atom (In formaldehyde both attachments to the carbonyl are hydrogen atoms) In the ketones the carbonyl always carries two hydrocarbon radicals which may be the same (simple ketones) or different (mixed ketones)

The ketones are far less reactive than the aldehydes They are sufficiently resistant to oxidation to be unaffected by Fehling's and Benedict's reagents This difference in reactivity of aldehydes and ketones is due primarily to the fact that in the ketones there is no hydrogen attached to the carbonyl group When ketones are oxidized by powerful oxidizers the carbon chain is broken and carboxylic acids with fewer carbon atoms are formed \*

### An Important Ketone

The most important ketone is the simplest one, dimethyl ketone, better known as acetone. The oxidation of isopropyl alcohol produces this compound. Acetone is a volatile liquid with a boiling point of 56° C. It is readily soluble in water. Industrially this ketone is one of the important solvents, particularly suitable for dissolving fats oils resins, and gums. Adhesive tape can be removed with acetone.

It is interesting to note that acetone is normally present in the blood in very small amounts. Larger quantities of acetone in the blood and urine are indicative of a faulty fat metabolism. This may be evidenced as diabetes mellitus (sugar diabetes). In severe cases of this affliction the amount of acetone produced is sufficient for its detection in the breath and the urine by reason of its characteristic sweetish odor.

#### SELECTESTING QUESTIONS

- 26 How does the ketone differ from the aldehyde in structure?
- 27 What is the carbonyl group? Do both aldehydes and ketones contain this group?
- 28 How is the ketone related to the secondary alcohol?
- 29 How do aldehydes and ketones compare in ease of oxidation?
- 30 What is the structural formula for acetone? Why is it the simplest possible ketone?

<sup>\*</sup>CH<sub>3</sub> CO CH<sub>3</sub>COOH + H<sub>2</sub>CO<sub>3</sub> Oxidation of a ketone breaks the carbon chain next to the carbonyl group

#### IV. THE ETHERS

## Nature of Ethers:

Because of the presence of the hydroxyl group in the alcohol it becomes possible to link together two alcohol molecules by dehydra ton (loss of water) and form new structures called ethers. There are many ethers, yet all of them are based on the type formula R—O—R' They may therefore be looked upon as oxides of an organic character. In theory an ether may be viewed as the result of replacing the hydrogen of the —OH group of the alcohol by an R group, or as the result of replacing both hydrogens of the water molecule with R groups.

The accompanying table gives names and formulas for a number of the lower molecular weight ethers

#### ETHERS

Name	Condensed Structure	
Dimethyl ether Methyl ethyl ether Diethyl ether Methyl n propyl ether Methyl n sopropyl ether etc	CH <sub>3</sub> -O-CH <sub>3</sub> CH <sub>3</sub> -O-CH <sub>2</sub> CH <sub>3</sub> CH <sub>3</sub> -CH <sub>2</sub> -O-CH <sub>2</sub> CH <sub>3</sub> CH <sub>3</sub> -O-CH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub> CH <sub>3</sub> -O-CH <sub>2</sub> CH <sub>3</sub> ) stomers	

The last three ethers listed in the table are isomers, all have the same molecular formula,  $C_1 H_{10}O$  Those ethers which have the same radical for R and R' are classified as simple ethers. When different radicals are attached to the oxygen the substance is a mixed ether. Notice that two simple and three mixed ethers appear in the table. The characteristic linkage in the ether molecule is C-O-C

Ethers are but slightly soluble in water, and the solubility decreases rapidly with increasing molecular weight. Ethyl ether (duethyl ether) is soluble in water to the extent of only about 7 per cent, it is a highly volatile liquid which boils at 35° C, a tem perature not far above room temperature, and actually below that of the body

### Preparation and Properties of Ethyl Ether

Diethyl ether, ordinarily called ethyl ether or simply ether, is the most important. It can be prepared quite efficiently from ethyl alcohol by reaction with sulfuric acid

(1) 
$$C_2H_5OH + H_2SO_4 \rightarrow C_2H_5OSO_3H + H_2O_3$$

(2) 
$$C_2H_5OSO_3H + C_2H_5OH \rightarrow C_9H_5 - O - C_2H_5 + H_9SO_4$$

The equations describe the two steps in the process An inspection of these equations shows that the net result is the elimination of a molecule of water from two molecules of ethyl alcohol

$$C_9H_5OH$$
  $\rightarrow$   $(C_2H_5)_2O+H_9O$   $C_2HOH$ 

The function of the sulfuric acid is to accomplish this type of dehydration

Chemically the ethers are quite mert. For example, they fail to react with sodium metal, aqueous oxidizers, strong alkalies, and cold mineral acids. However, ethers are combustible, the lower molecular weight ones are highly flammable, and their vapors form explosive mixtures with air. This inherent danger must be kept in mind when using ethyl ether for solvent purposes, or as an anesthetic

Although ethyl ether is known to most people simply as ether the student of chemistry finds that it is but one of many compounds classified as ethers. Ethyl ether and isopropyl ether in particular are widely used as solvents or extractives for fats, oils resins, etc. However, their volatility, flammability, and explosive ness when mixed with air make these ethers, and the other lower members of the series, exceedingly hazardous to work with

Of all the anesthetics, ether requires less skill in its administration and its margin of safety is greater. It is slower in its action, but more lasting in its effects, and causes a greater relaxation of the muscles than does introus oxide chloroform, or ethylene. Moreover, during ether anesthesia the pulse, respiration, and blood pressure of the patient remain normal or slightly above. The occasional nausea of the patient and the irritating action on the kidneys and respiratory system are the main objections to its use. To a considerable extent ether has been replaced by more pleasant anesthetics such as introus oxide oxygen and ethylene oxygen, and others. Ether for anesthesia is marketed in special containers.



Fig. 3—The Comforting Oblivion of Anesthesia. A surgical operation prior to the latter half of the 19th century was a horrible ordeal. What anesthetic could be given by the above method? Courlesy, Parke, Davis & Co., N. Y. C.

### Anesthetics:

Thus far a number of relatively simple compounds have been studied which have value as anesthetics. Choice is governed by a number of factors; nature of the surgery and the physical condition and tolerances of the patient are of course of primary consideration. On occasions it is desirable to start anesthesia with one substance, or combination of substances, and then later to change over to others. Thus vinyl ether, called Vinethene, is at times used as an induction agent in general anesthesia prior to ethyl ether.

The anesthetics listed in the table on page 304 are with one exception organic compounds.

### SELF-TESTING QUESTIONS

- 31. How does the structure of an ether compare with that of an alcohol? of water?
- 32. How does a simple ether differ from a mixed ether?
- 33. What is the method of preparation for ethyl ether?
- 34. What are the important uses of ethyl ether?
- 35. Why are the lower ethers dangerous to work with?
- 36 What are the advantages and the disadvantages of ethyl ether as an anesthetic?

- 37 Which compound given in the table of anesthetics is not organic?
- 38 Why can ethers be called hydrocarbon oxides?
- 39 Are diethyl ether and methyl n propyl ether homologues? are they isomers?
- 40 How does ethyl ether compare with ethyl alcohol in water solubility?

#### SOME ANESTHETICS

Name	Formula	Remarks
Chloroform	CHCl <sub>3</sub>	Nonflammable and nonurritating Has gradually been replaced by others
Cyclopropane	C <sub>3</sub> H <sub>6</sub>	General inhalation anesthetic Quick acting nonirritating no ill after effects
Ethyl chloride	CH₃CH₂Cl	Local anesthetic rapid evapora tion freezes tissue Not often used as an inhalation anesthetic
Ethylene	CH <sub>2</sub> =CH <sub>2</sub>	Excellent muscular relaxation rapid recovery
Ethyl ether	C2H5OC2H5	See discussion elsewhere in this section
Nitrous oxide	N <sub>2</sub> O	Used in dentistry and minor surgery
Vinyl ether	CH <sub>2</sub> =CHOCH=CH <sub>2</sub>	Convenient for short anesthesia May be used with N2O and with ethylene for better relaxation.

### SUGGESTED ACTIVITIES

- I THOUGHT PROVOKING QUESTIONS
  1 Why is formaldehyde a more powerful reducing agent than acetone?
  - 2 Why do some sugars act in the capacity of reducing agents?
    - 3 Why is grain alcohol used extensively by the pharmacist?
    - 4 What significance is attached to excessive acetone in the urine?
    - 5 Why is formic acid easily oxidized whereas acetic acid is not?
  - 5 Why is formic acid easily oxidized whereas acetic acid is not?
    6 Do all types of alcohols give carboxylic acids when treated with
  - aqueous oxidizing agents? Discuss
  - 7 How do ethers compare in chemical activity with (1) aldehydes (2) ketones (3) saturated hydrocarbons?
    - 8 How do you account for the fact that continued use of acctone to remove liquid nail polish causes the nails to become brittle?
    - 9 Under what conditions is ethanol considered to be a poison?
  - 10 When aldehydes are made by oxidizing primary alcohols why must they puckly be removed from the presence of the oxidizer?

II Vocabulary Testing of New Terms

alcohol
primary alcohol
secondary alcohol
tertiary alcohol
carbonyl

ether

ketone carboxylic acid polymerization carbonyl mixed ether simple ether polyhydric alcohol ethereal salts zymase formalin aldehyde induction anesthetic

III TOPICS FOR ORAL OR WRITTEN REPORTS

- 1 The Physiological Effects of Ethyl Alcohol
- 2 General Anesthesia
- 3 Industrial Uses of Alcohols
- 4 Clinical Testing for Blood Sugar

#### LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on page 714

# THE CARBOXYLIC ACIDS AND THEIR SALTS AND ESTERS, SOME CYCLIC COMPOUNDS

#### CHAPTER OUTLINE

- I CARBOXYLIC ACIDS (a) General characteristics of car
  - boxylic acids (b) Chemical properties of carbox
  - ylic acids (c) Formic and acetic acids
- (d) Polybasic carboxylic acids Hydroxy acids
- II ESTERS
- (a) The nature of esters

- (b) Chemical reactions
- III AROMATIC COMPOUNDS (a) The aromatic ring
  - (b) Some typical aromatic com pounds
- IV HETEROCYCLIC COMPOUNDS
- (a) The heterocyclic ring (b) Some heterocyclic compounds

### I. CARBOXYLIC ACIDS

### General Characteristics of Carboxvlic Acids:

In the preceding chapter it was shown that the oxidation of a primary alcohol produces first an aldehyde, and that the aldehyde in turn is readily oxidized to a carboxylic acid. Using O to indicate oxygen from an aqueous oxidizing agent, for example, potassium dichromate solution acidified with sulfuric acid, the following formulas picture the steps in the formation of acetic acid from ethyl alcohol:

CH<sub>3</sub>CH<sub>2</sub>OH 
$$\xrightarrow{\bullet}$$
 CH<sub>3</sub>C—H  $\xrightarrow{\bullet}$  CH<sub>3</sub>C—Ot  
Ethyl olcohol Acetaldehyde Aceta acid

From this it should be apparent that carboxylic acids can be made by the exidation of primary alcohols or aldehydes as the starting materials. Usually the alcohol is the more available.

The general formula for monobasic carboxylic acids, known also

as fatty acids, is R-C-OH. The -C-OH group, which is the characteristic structural features of all carboxylic acids, is called the carboxyl group. As will become apparent, the properties of the carboxylic acids stem largely from this group.

The table gives the names for the first several members in the series of saturated aliphatic acids which have one carboxyl group per molecule

	CAPROVVIIC	

Name	Formula	Possible Structures
Formic acid	нсоон	1
Acetic scid	CH <sub>2</sub> COOH	1
Propionie acid	CH <sub>2</sub> CH <sub>2</sub> COOH	1 1
Butyric acids	C <sub>2</sub> H <sub>2</sub> COOH	2
Valeric acids etc	C4H,COOH	4

Note from the table that, beginning with the butyric acids, isomerism becomes a characteristic of this homologous series. The two butyric acids are identified by the following structural formulas and names.

In this series of acids the first members are clear liquids, those above nine carbon atoms of normal chain structure are solids. Two higher members of this series, not given in the table, are palmitte and stearic acids, formulas C<sub>18</sub>H<sub>31</sub>COOH and C<sub>17</sub>H<sub>32</sub>COOH, respectively. These two solid acids are found in the structures of many animal and vegetable fats and oils in the form of glyceryl esters.

The lower fatty ands are completely soluble in water, but starting with the valeric acids solubility in water decreases rapidly with increasing molecular weight. Formic, acetic, and propionic acids have sharp odors. Beginning with the butyric acids those which are sufficiently volatile have extremely disagreeable odors. The odor of rancel butter is due to free butyric acid.

# Chemical Properties of Carboxylıc Acids:

The carboxylic acids vary somewhat in strength, but in general they are classified as weak acids. This means that the water soluble ones dissociate only to a small degree to give hydrogen ions. (Recall that the strength of an acid is measured in terms of its dissociation to provide free hydrogen ions.) Acetic acid, for example, in a 5 per cent aqueous concentration, is ionized to the extent of about 15 per cent. Notice that in the ionic dissociation

the hydrogen ion comes from the carboxyl group of the acid, other hydrogens present in the molecule are not the source of hydrogens ones. While the carboxylic acids are relatively weak, they are nevertheless stronger than carbonic acid. Solutions of the soluble carboxylic acids have the characteristic sour taste and redden blue litmus paper.

Carboxylic acids, excepting formic, are quite resistant to oxida tion by aqueous oxidizers. Formic acid is very easily oxidized. An examination of its structure shows that unlike its homologues this acid has a hydrogen atom attached directly to the carboxyl radical, hence, formic acid possesses the character of an aldehyde as well as that of the carboxylic acid.

A typical reaction of carboxylic acids is salt formation. This can be accomplished by treating the acid with a base in a neutralization type of reaction. In this manner, sodium acetate can be made from acetic acid.

Many of the salts of carboxylic acids are water soluble and highly ionized, hence strong electrolytes. Some have value in medicine. The table on page 312 gives names, formulas, and uses for a number of typical salts derived from organic acids.

Carboxylic acids react with alcohols to give a class of compounds known as organic esters. A well known liquid ester is ethyl acetate, prepared from ethyl alcohol and acetic acid. This type of reaction shows some similarity to inorganic reactions of neutralization, and accounts for the older name, ethereal salt, for the ester

The preparation of an ester in this manner illustrates a type of organic reaction which does not go to completion, but instead reaches a point of chemical equilibrium. When ethyl alcohol and acetic acid are brought together in equal molar quantities the equilibrium is established after about two thirds of each has reacted. In order to get the reaction to progress further in the direction of completion, i.e., ester formation, something must be done to "upset" the ester equilibrium for example, the continuous removal of the water or the ester from the reaction mixture Reactions which attain equilibrium, and therefore do not go to completion, are frequently encountered in organic chemistry. More will be mentioned about esters in a later section, notice, however, that this type of reaction can be written in terms of general formulas

### Formic and Acetic Acids

Formic and is somewhat stronger than its homologues. It is a clear liquid which boils at 101° C. Contact of this acid with the skin causes blisters, the stinging sensition and blistering which result from the bites of insects such as bees mosquitos, and ants is due to the injection of formic acid through the skin. The irritation can be reheved by washing the affected area with soap or dilute ammonia water to neutralize the acid. In industry, formic acid is employed in processes for dyeing textiles, and for removing hair from hides

Acetic acid is the acid of vinegar Cidar vinegar is produced by air oxidation of the ethyl alcohol which is present in "hard" cider

O

Bacterium acet

CH<sub>3</sub>CH<sub>2</sub>OH 
$$\dotplus$$
 O<sub>2</sub>

CH<sub>3</sub>C—OH  $\dotplus$  H<sub>2</sub>O

Vinegar contains from 4 to 5 per cent of acetic acid

Glacial acetic acid is practically free from water and approximately 99 5 per cent pure CH<sub>3</sub>COOH It is so called because it freezes to an ice like solid at 16 7° C. This acid is undoubtedly the best known and most widely used of the carboxylic acids. In industry it has value as a solvent and as a starting material for synthesizing numerous other organic compounds.

# Polybasic Carboxylic Acids. Hydroxy Acids.

The organic acids dealt with thus far have contained one carboxyl group and hence one ionizable hydrogen in the molecule. There are some acids which have two carboxyl groups in the molecule, some with three, etc. Oxalic acid, with two carboxyl groups, is a dibasic acid, and citric acid, with three carboxyl groups, is tribasic.

The hydroxy acids include monobasic and polybasic carboxylic acids which also contain one or more hydroxyl groups in the mole cule. A number of the fruit acids are hydroxy acids. For the most part the hydroxy acids exhibit a chemical behavior which is characteristic of the carboxyl group and of the type of alcohol structure which is present

Following are the names and structures for a few polybasic and hydroxy acids. While the student may not be expected to write some of these more complex structures, it should be realized that those which appear here are important ones.

Oxalic acid is a white crystalline, water soluble solid, actual composition (COOH)<sub>2</sub> 2 H<sub>2</sub>O, hence a dihydrate. It is the strongest of the carboxylic acids, and this property must be observed in using it. Oxalic acid occurs in nature in the form of salls in certain plants, for example, rhubarb and sorrel. Like other dibasic acids it forms two series of salls, i. e. acid salls and normal salls.

Lactic acid is produced when milk sours, it is found also in sauerkraut. We shall learn later that lactic acid plays a role in metabolism, and that it is a normal constituent of muscle tissue

Citric and tartanc acids are important fruit acids, and the former, as its name implies, is found in citrus fruits. Tartanc acid, free and also in the form of salts, occurs in grapes, and in the deposits which form in wine casks.

The accompanying table presents some of the typical salts of a number of organic acids

SALTS	OF	CARBOXYLIC	ACIDS

Name	Formula	Uses
Calcium lactate	(CH <sub>3</sub> CHOHCOO)-Ca	Medicinally for calcium deficiency
Calcium propionate	(CH <sub>3</sub> CH <sub>2</sub> COO) <sub>2</sub> Ca	Prevention of molding of bread
Lead acetate	(CH₃COO)₂Pb	Treating poison ivy, skin
Magnesium citrate	Mg3(C6H5O7)2	Saline purgative
Potassium acid tartrate (cream of tartar)	KH C <sub>4</sub> H <sub>4</sub> O <sub>6</sub>	Tartrate baking powders
Sodium citrate	Na <sub>3</sub> C <sub>6</sub> H <sub>5</sub> O <sub>7</sub>	Prevention of blood clot ting in transfusions
Zinc stearate	(C <sub>17</sub> H <sub>35</sub> COO) <sub>2</sub> Zn	Dusting powders oint ments

The amino acids are substituted carboxylic acids. Because of their close association with proteins the amino acids are more profitably discussed in a later chapter.

#### SELF-TESTING QUESTIONS

- 1 What 19 the name and the structure of the characteristic group of a carboxylic acid?
- 2 How do organic acids compare with inorganic acids in respect to ionization and acid properties?

3 What are three important chemical properties of carboxylic acids?

4 Which carboxylic acids are of outstanding importance? Why?

- 5 What are three important hydroxy acids? How many carboxyl groups does each contain?
- 6 How does exalic acid compare in strength with other carboxylic acids? What must be true about its ionization?
- 7 Which salts of organic acids have use in medicine? In what way?
- 8 How would you proceed to make calcium lactate by a neutralization method?

#### II. FSTERS

#### The Nature of Esters:

In discussing the carboxylic acids it was pointed out that the esters have the general formula RCOOR' For those esters which are derived from formic acid the first R in the generalized formula is a hydrogen atom. For all other esters both R and R' are hydrocarbon radicals.

#### SOME ESTERS

Name	Formula	
Methyl formate	о Н-С-о-сн <sub>з</sub>	
Methyl acetate	O CH <sub>3</sub> -C-O-CH <sub>3</sub>	
Ethyl acetate	O CH3-C-O-CH2CH3	
Methyl propionate	O CH <sub>3</sub> CH <sub>2</sub> —C—O—CH <sub>3</sub>	
n Propyl acetate	O CH <sub>3</sub> —C-O-CH <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub>	

The most used method for the preparation of the ester is by direct reaction between the carboxylic acid and the alcohol This approach is termed esterification. A trace of sulfuric acid is often used to catalyze the process, larger amounts of sulfuric acid absorb the water produced, and shift the equilibrium in the direction of ester formation. In the equations which follow for esterification

the first one is in general terms. Observe how this then applies specifically to the synthesis of n propyl acetate

Numerous esters are found in nature and they account for the fragrant odors of many flowers and fruits. Their pleasant odors make them valuable for use in perfumery and in the preparation of synthetic flavorings. Some esters, for example, ethyl acetate and butyl acetate, are important solvents in lacquers. Finger nail polish illustrates such a use.

ODORS OF ESTERS

Name	Formula	Odor
Amyl acetate	O CH <sub>3</sub> CO(CH <sub>2</sub> ) <sub>4</sub> CH <sub>3</sub>	Apricot
Amyl butyrate	O CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> C—O—(CH <sub>2</sub> ) <sub>4</sub> CH <sub>3</sub>	Pear
Ethyl butyrate	CH <sub>3</sub> (CH <sub>2</sub> ) <sub>2</sub> C—O—CH <sub>2</sub> CH <sub>3</sub>	Pineapple
Ethyl formate	HC-O-CH₂CH₃	Rum
Isoamyl acetate	CH <sub>3</sub> C—O—(CH <sub>2</sub> ) <sub>3</sub> CH(CH <sub>3</sub> ) <sub>2</sub>	Banana
Octyl acetate	CH <sub>3</sub> C—O—(CH <sub>2</sub> ) <sub>7</sub> CH <sub>3</sub>	Orange

### Chemical Reactions

Esters are essentially netural compounds and they are not as reactive as the acids and alcohols from which they are prepared

Two rather closely related reactions of esters will be considered, these are hydrolysis and saponification. In hydrolysis the ester reacts with water to give a carboxylic acid and an alcohol. Hydrolysis reactions are usually promoted by use of acids, bases, enzymes, etc, as catalysis. Notice that the hydrolysis of the ester is just

O O 
$$\parallel$$
  $\parallel$   $R-C-O-R'+HOH \rightleftharpoons R-C-OH+R'OH$  Ester Acd Alcohol

the opposite of its preparation via esterification, and results in an equilibrium

The sapomification of an ester is carried out by the use of strong aqueous alkali, for example, sodium hydroxide solution. Reactions of sapomification go to completion. The equation for the sapomification of ethyl acetate follows.

$$\begin{array}{ccccc} O & O \\ & & & \\ CH_3C--OC_2H_5 + NaOH \rightarrow CH_3C--ONa + C_2H_5OH \\ & & \\ Ethyl accetate & Alkall & Sad um scelate & Ethyl alcohol \\ \end{array}$$

The discussion of animal and vegetable fats and oils, which are esters of glycerol and higher fatty acids, is presented in a later chapter. The waxes which are secretions from many plants and animals are also esters. Beeswax from bees spermaceti from the sperm whale, and lanolin from wool are three important waxes.

#### SELF-TESTING QUESTIONS

- 9 What are the reactants in the preparation of an ester by the process called esterification? 10 Does the reaction for ester preparation via esterification go to
- completion?

  11 What is the nature of a reversible reaction? What is true when such a
- reaction is at a state of equilibrium?
- 12 In the preparation of an ester from an alcohol and a carboxylic acid why does the removal of water upset the equilibrium?
- 13 What is noteworthy about the odors of esters? What value do esters have?
- 14 How does saponification differ from hydrolysis?
- 15 Write the structure for the ester, ethyl formate What other ester is isomeric with ethyl formate?

### III. AROMATIC COMPOUNDS

### The Aromatic Ring

We have learned that the aromatic hydrocarbons have a ring or cyclic type of structure, and that the simplest of these hydrocarbons is benzene,  $C_rH_6$  The structural formula for benzene is as follows

This arrangement of six carbons in a ring, with the alternate single and double bonds, constitutes the so called aromatic or benzene ring structure. In its chemistry benzene does not behave like a highly unsaturated compound. Newer theories suggest that the extra pairs of electrons which are pictured as giving the double bonds are actually uniformly dispersed around the ring so that all six ring bonds, and all six carbon atoms, are equivalent. The most characteristic reaction of the benzene ring is substitution wherein one or more hydrogen atoms are replaced by other atoms or groups of atoms.

For simplicity it is a common practice to indicate the structure of the benzene ring by the use of a hexagon with the alternate single and double bonds. When this notation is used it is understood that at each corner of the hexagon there is a carbon atom,

and that each carbon atom has a hydrogen atom attached unless some other atom or group has replaced the hydrogen

Inasmuch as all six hydrogens of benzene are equivalent it makes

no difference which one is replaced in monosubstitution; only one compound can result. This is illustrated by inspection of the structural formula for monochlorobenzene. However, when two substituents appear, three isomers are possible. The following structural formulas for the three isomeric dichlorobenzenes illustrate this:

1.2 dichlorobenzene





para dichlorobenzene 1.4 dichlorobenzene

Notice from the structures that there are three possible ways of placing the two substituents, in this case chlorine atoms. When the two substituents are attached to adjacent carbon atoms the structure is identified as ortho, abbreviated o-. In the meta structure, abbreviated m-, the substituents are on carbons which are separated by one carbon. For the para, abbreviated p-, the substituents are attached to carbons which are separated by two carbons. Also, instead of the use of the prefixes o-, m-, and p-, numbers may be used to indicate the positions occupied by substituents. In numbering it is conventional to start with a carbon which carries a substituent and proceed in a clockwise direction around the ring.

# Some Typical Aromatic Compounds:

A study of aromatic compounds in any detail is beyond the scope and intent of this textbook. However, structures are given in this section for a number of typical aromatic compounds. Some of these have medicinal value.

Phenol, commonly called carbolic acid, is a highly corrosive and toxic compound. Children have been fatally poisoned by accidentally swallowing phenol: it should never be left in unlocked medicine cabinets within reach of the very young and unwary When properly diluted phenol is an excellent disinfectant and antiseptic. The name carbolic acid for phenol must never be confused with a similar name, carbonic acid, which is a harmless solution of carbon dioxide in water.

Sodium salicylate, unlike salicylic acid, is soluble in water. This salt has limited use as a food preservative, for example, in catsups Medicinally, sodium salicylate is used to relieve rheumatic pain and to reduce fever.

The acetyl ester of salicylic acid is commonly known as aspirin Several thousand tons are manufactured annually in the United States Aspirin enjoys wide usage for relieving pain (analgesic) and for reducing fever (antipyretic) Likely its activity is due to the fact that in the body it hydrolyzes to give salicylic acid

Phenyl salicylate, or salol, is used as an intestinal antiseptic, and also as an antipyretic and antirheumatic. Methyl salicylate, also derived from salicylic acid, is commonly called oil of wintergreen. It finds wide usage as an ingredient in liminents.

#### SELF-TESTING QUESTIONS

- 16 What are the structural characteristics of the aromatic ring?
- 17 How many monosubstitution products of benzene are possible? Why?
  18 Which is the more characteristic reaction of benzene addition or
- 18 Which is the more characteristic reaction of benzene addition o substitution?
- 19 What is the significance of the prefixes ortho meta and para?
- 20 The structure for p cresol has been given How many cresols are possible? What are the others?
- 21 How many of the structures given in this section are esters?
- 22 Lysol contains cresols For what purpose is Lysol used?

### IV. HETEROCYCLIC COMPOUNDS

### The Heterocyclic Rings

Thus far the cylic structures dealt with have been confined to rings of carbon atoms. These are termed carbocyclics. In the heterocyclic compounds the ring contains in addition to carbon atoms one or more atoms of other elements. The most important of these are nitrogen, oxygen and sulfur. Unlike the aromatic ring the number of atoms constituting the ring of a heterocyclic need not be six.

Heterocyclic compounds have a wide distribution in both plants and animals Heterocyclic rings appear in some of the more com

plex molecules, for example, many vitamins, plant pigments, enzymes, alkaloids, and drugs

# Some Heterocyclic Compounds:

The structures for a number of the illustrative heterocyclic compounds follow

Each of these compounds may be viewed as a parent structure from which numerous derivatives are possible. Thus the pyrrole ring appears in the hemin of hemoglobin, and also in chlorophyll. This same ring, in reduced form, constitutes a portion of the structure of the amino acids proline and hydroxyproline. Obviously pyrrole is a hetero ring of considerable biological significance

The pyridine nucleus is found in several of the alkaloids. One of the B complex of vitamins, nicotinamide, is a derivative of pyridine. Pyridine itself is produced in the destructive distillation of hones.

Some of the heterocyclics, both natural and synthetic, contain two rings in the molecule

Nicotine consists of a molecule of pyridine joined to a molecule of a reduced pyrrole (pyrrolidine) It is one of the simpler of the alkaloids, and occurs in the tobacco plant

Purme itself is of little importance, but it has numerous important derivatives. Caffeine and uric acid are two of the better known derivatives of purme. Uric acid is a product of the hydrolysis of nucleic acids which occur in plants and animals as nucleoproteins. Small amounts of uric acid occur in the blood as a metabolic product.

In the structure for sulfathiazole both the aromatic ring and a heterocyclic ring appear. Other sulfa drugs have other groups of atoms in some instances heterocyclic rings in place of the thiazole ring.

#### SELF-TESTING QUESTIONS

- 23 How does the carbocyclic differ from the heterocyclic?
- 24 In what classification would you place the aromatic compounds? The cycloparaffins?
- 25 What elements are most usual in the heterocyclic rings?
- 26 What are some of the substances of physiological importance which contain heterocyclic rings?

### SUGGESTED ACTIVITIES

- I THOUGHT PROVOKING QUESTIONS
  - 1 From an inspection of the structural formulas of formic acid and acetic acid how may one account for the fact that only formic acid is a reducing agent?
  - 2 In what manner is the formation of the eater similar to the inorganic reaction of neutralization? Are ethereal salts similar in properties to inorganic salts?

- 3 How do you explain the fact that metabolism of the fruit acids such as citric acid produces an alkaline effect in the body?
- such as citric acid produces an alkaline effect in the body?

  4 How does propionic acid ionize in water? What is the equation for its neutralization?
- 5 What products result from the hydrolysis of ethyl n butyrate? What is formed when this ester is sapomified?
- 6 Acetic and and other organic acids of its series will react with sodium carbonate to evolve carbon dioxide. What does this prove about the relative strengths of carboxylic acids and carbonic acid?
  - 7 How are the various sulfa drugs related to sulfamilamide?
- 8 What is the food source of the uric acid which is present in small amount in the blood and also in the urine?
- 9 In what respect do hemoglobin and chlorophyll have a similarity of structure?
- 10 Look up the structure of the vitamin known as macin. How is it related to pyridme?

## II Vocabulary Testing of New Terms

carboxyl group	ortho	carbocyche
ester	meta	heterocyclic
esterification	para	sulfa drug
hydroxy acid	antipyretic	saponification
aromatic ring	derivative	analgesic

- III Topics for Oral or Written Reports
  - 1 Esters for Medicinal and Industrial Use
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#### LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on page 714

### CARBOHYDRATES

#### CHAPTER OUTLINE

- I, OCCURRENCE, CLASSIFICATION, AND III. PRINCIPAL CARBOHYDRATES STRUCTURE OF CARBOHYDRATES-
  - (a) Occurrence and importance
  - (b) Composition and classification
  - (c) Structure
- II. CHRMICAL PROPERTIES OF CARBO-HYDRATES.
  - (a) Reducing properties of carbohydrates
  - (b) Hydrolysis of carbohydrates
    - (c) Fermentation of carbohydrates (d) Oxidation of carbohydrates
    - (e) Reactasalcohols-esterification
    - (f) Reduction of carbohydrates (g) Form osazones

- (a) The monosaccharides
  - (b) The disacchandes
  - (c) The polysacchandes
- IV. CELLULOSE:
  - (a) Physiological uses of cellulose (b) Commercial uses of cellulose
    - products 1. Cellulose nitrate
    - 2. Cellulose acetate
    - 3 Mercerized cotton
    - 4. Artificial silk

    - 5. Cellophane 6. Paper 7. Ethyl cellulose, carboxymethylcellulose

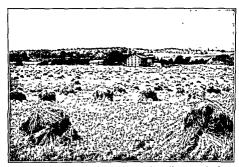


Fig. 1-An Important Source of Carbohydrate, Wheat, How many other food products can you name that are sources of carbohydrates? Courtesy, Ohio State Experiment Station.

# I. OCCURRENCE, CLASSIFICATION, AND STRUCTURE OF CARBOHYDRATES

# Occurrence and Importance

Carbohydrates, one of three great classes of foods, are very important from a physiological standpoint, since they include the starches. In addition to starches and sugars, the term carbohydrate includes cellulose, which is the major constituent of the woody or fibrous part of all plants, and is the ultimate source of some of our fuel (wood, coal), much of our clothing (cotton, linen, rayon), and a large part of our building material (wood). In roots and seeds and in vegetables and unripe fruits, the carbo hydrates occur as starch, but as fruits ripen the starch is converted into sugar.

# Composition and Classification:

Carbohydrates contain three tasteless elements carbon, hy drogen, and oxygen, the last two elements, with but insignificant exceptions, being present in the same ratio as in water, namely two atoms of hydrogen to one of oxygen. It is for this reason that the general formula of most carbohydrates can be represented as  $C_1(H_2O)$ . Thus in the formula of sucrose (cane, beet sugar),  $C_{12}H_{22}O_{11}$ , the ratio of the atoms of hydrogen to the atoms of oxygen is 2 to 1, the same as in  $H_2O$  as the name implies, carbo hydrates means "hydrates of carbon" However, the name is somewhat misleading since the hydrogen and oxygen do not exist as water of hydration in a carbohydrate Carbohydrates are best defined as polyhydroxy aldehydes, polyhydroxy hetones or substances which can be hydrofyzed to gue these structures. This will be borne out later in the structures for simple sugars and in the study of the hydrofyzed moduscachardes

There are several ways of classifying the carbohydrates. In general they form two classes those that are sweet, crystalline solids, called sugars, and those that are tasteless noncrystalline solids, called starches and celluloses. From their chemical behavior with water (hydrofysis), carbohydrates may be classified according to the number of saccharde ( $C_6H_{10}O_3$ ) groups in their molecules, the monosacchardes containing one, the disacchardes two, and polysacchardes three or more of these groups. The term saccharde

<sup>•</sup> Acetic scid CH<sub>3</sub> COOH and lactic scid CH<sub>3</sub> CHOH COOH contain H and O in the ratio as found in water but are not carbohydrates. Furthermore several compounds such as rhamnose CeH<sub>12</sub>O<sub>3</sub> do not have their H to O in the ratio of 2 1 but are grouped with the carbohydrates on account of similarity in their properties

### CLASSIFICATION OF IMPORTANT CARBOHYDRATES

Classification	Examples	Some Properties
Monosaccharides (C <sub>6</sub> H <sub>10</sub> O <sub>5</sub> ) <sub>1</sub> ·H <sub>2</sub> O or C <sub>6</sub> H <sub>12</sub> O <sub>6</sub> Cannot be hydrolyzed	Glucose Fructose Galactose	Crystalline, sweet, very soluble, require no diges tion
Disacchandes (C <sub>0</sub> H <sub>10</sub> O <sub>5</sub> ) <sub>2</sub> H <sub>2</sub> O or C <sub>12</sub> H <sub>22</sub> O <sub>11</sub> Can be hydrolyzed	Sucrose Lactose Maltose	Crystalline, sweet, soluble, digestible
Polysaccharides (CaHioOs). Can be bydrolyzed (Since the molecular weight is un known a refers to an unknown number of these groups)	Starch Dextrin Cellulose Glycogen	Amorphous, with little or no flavor, less soluble Vary in solubility and di gestibility Form col loidal dispersions which cannot be dialyzed

means sweet and should not be confused with the term "saccharine," which is a coal tar compound that bears no relation to a carbohydrate (Saccharine is approximately 500 times as sweet as cane sugar, but it has no nutritive value, since it is not digestible and is eliminated from the body unaltered)

The monosacchandes are still further classified on the basis of the number of carbon atoms in the molecule, as pentoses,  $C_5H_{12}O_5$ , etc., of which the hexoses are the most abundant and most important

### Structure:

Following are the structural formulas for two important mono saccharides, glucose, an aldohexose, and fructose, a ketohexose

The structure for glucose reveals the aldehyde group at carbon number one. In the structure for fructose a ketone group appears at carbon number two. From these formulas it is evident that in the monosaccharide molecule all carbons are joined in one chain, and that the structure may be regarded as a polyhydric alcohol which contains either the aldehyde or the ketone group. Conse quently the chemical behavior of a monosaccharide is due to the presence of the following groups.

In order to distinguish between aldehyde and ketone types of monosacchardes the terms aldose and ketose are used, the "ose" signifying a sugar Thus the name aldohexose represents a six carbon atom sugar with an aldehyde configuration

The carbon atoms numbered 2, 3, 4, and 5 in the glucose molecule are called asymmetric (without symmetry) because each one has four unlike factors attached to it Isomeric structures then become possible through a variation of the relative positions which the attached factors occupy in space. The glucose molecule pictured here is but one of sixteen aldohexoses. Chemists indicate this by writing the structure for ordinary glucose with the hydroxyl group attached to carbon number three placed on the left, while the hydroxyl groups on carbons two, four, and five are written on the right

Some of the chemical reactions of glucose, as well as other sugars, suggest that the open chain structure with its free aldehyde (or ketone) group exists only to a small degree Cyclic structures have therefore come into use for the sugars

In the cyclic structures for glucose the free aldehyde group does not appear, it is, however, said to be potentially free Undoubtedly in solution an equilibrium exists between the ring and the open chain forms, with the ring form predominating

The disaccharide structure shows two molecules of monosac charide linked together by the elimination of one molecule of water

to form an oxygen (ether) bridge. The resulting disaccharide may still have a potentially free aldehyde or ketone group, and if such is the case it will show the properties of the aldehyde or ketone, just as do glucose and fructose. There is one important disaccharide, namely, sucrose, which does not have any reducing properties. Evidence shows that for this sugar the aldehyde group of glucose and the ketone group of fructose have both been utilized in forming the new oxygen linkage, and hence both have been destroyed as reducing groups. In contrast to sucrose, the disaccharide maltose is a reducing sugar since it possesses a potentially free aldehyde group, indicated by the arrow in the following structures for this sugar. Lactose is very similar to maltose.

The polysaccharides have variable molecular weights with numer ous carbon chains linked together through oxygen atoms. Like sucrose, the polysaccharides are nonreducing carbohydrates. They may be considered as composed of hexose molecules less one mole cule of water for each hexose molecule present. The formula be comes  $(C_6H_{10}O_5)_{\rm s}$ , where n refers to the number of  $C_6H_{10}O_5$  residues in the structure

### SELF-TESTING QUESTIONS

- 1 What substances are included under the name of carbohydrates?
- 2 In what forms are carbohydrates stored up in plants?
- Define carbohydrate from its atomic composition, from its characteristic groupings.
- 4 What is the distinction between saccharide and saccharine?
- 5 What is an aldose? a ketose?

properties?

- 6 To what are the reducing properties of sugar attributed?
  7 What disaccharide does not have reducing properties?
- What disaccharide does not have reducing properties.

  How do the three classes of carbohydrates compare in their physical

# II. CHEMICAL PROPERTIES OF CARBOHYDRATES

As has been mentioned the chemical behavior of a carbohydrate is determined by the presence of the aldehyde or ketone structure and the primary and secondary alcohol groups. With this in mind, and an understanding of the properties of such groups, the reactions of the carbohydrates are somewhat simplified

# 1. Reducing Properties of Carbohydrates

The monosaccharides and the disaccharides, with the exception of sucrose, are good reducing compounds because of the presence of a free, or potentially free, aldehyde or ketone group Sucrose, and the polysacchandes, however, show little or no reducing action with oxidizing agents, because of the absence of reducing groups When these oxidation reduction reactions once start the alcohol groups are then affected by oxidation. It is often important to discover if glucose is present in foods, or in such waste matter as the urine Glucose is the only sugar of great physiological signifi cance in the urine Here, the presence of glucose indicates glyco suria, the chief symptom of diabetes. Since glucose sugar has a great affinity for oxygen, 1 e, 1t has reducing properties on ac count of its aldehyde group, it is easy to make a test for this sugar Benedict's and Fehling's solutions are the reagents very commonly used for this test Benedict's solution, which is a modification of Fehling's solution has many advantages over other solutions used to test for sugar in the urine. This solution is a permanent single solution, and, in contrast to Fehling's solution, is less alkaline and more sensitive to reducing sugars. Moreover, it is not affected by uric acid, creatinine, or chloroform, the latter compound being sometimes employed as a preservative for specimens of urine Benedict's and Fehling's solutions both contain soluble cupric hydroxide Either deep blue alkaline solution, if boiled with any solution containing glucose (an aldehyde sugar), is reduced to form a reddish yellow\* precipitate of cuprous oxide and an organic acid as explained in the following equation

<sup>\*</sup>The yellow precipitate first formed is CuOH which on long boiling changes to red Cu<sub>2</sub>O Just a face of yellow precipitate in the presence of blue cupric ions imparts a reven color to the solution. If conducins are casefully controlled and Benedict's or Fehling's solutions are carefully prepared the test may be used as a quantitative method for the determination of a reducing sugar such solution being made of such a strength that a definite volume will be reduced to Cu<sub>2</sub>O by exactly 0.05 Gm of glucose Fructose a hydroxy kebos differs from ordinary kebones by reducing Fehling's solution.

Milk sugar, or lactose, is also a reducing sugar, and consequently the urine of pregnant and nursing women will give the same test as glucose sugar. On the other hand, milk sugar does not ferment with yeast, as does clucose

# 2. Hydrolysis of Carbohydrates

In the presence of certain nonomizing dilute acids like HCl or in the presence of certain enzymest both the disaccharides and poly saccharides react with water to yield molecules of monosaccharides If acid causes the change the final product is a monosaccharide, but with enzymes (amylases) the end product of the hydrolysis of a polysaccharide such as starch is the disaccharide, maltose

Hydrolysis by acids

Hydrolysis by amylases

$$(C_6H_{10}O_5)n + \frac{n}{2}H_2O \rightarrow \frac{n}{2}C_{12}H_{22}O_{11}$$

† Enzymes or ferments are catalyzers produced by living organisms

### DIGESTION OF CARBOHYDRATES

Enzyme	Found in	Carbohydrates	End Product
Sucrase (invertase) Maltase Lactase	Intestine Intestine Intestine	Sucrose Maltose Lactose	Glucose and fructose Glucose Glucose and galactose
Salivary amylase (ptyahn) Pancreatic amylase	Saliva (mouth) Pancreas	Starch Starch	Dextrin to maltose  Dextrin to maltose
(amylopsin) Glycogenase	Laver	Glycogen (liver starch)	Glucose

In organic chemistry, this kind of a chemical decomposition in volving writer is called hydrolvsis. In a previous chapter we learned (p. 182) that hydrolysis is the reaction of a salt with water to form an acid and a base. Now in a broader sense, hydrolysis represents reactions of compounds other than salts with water.

The table on page 330 shows the hydrolytic changes in the carbohydrates as produced by the different enzymes in the body

# 3 Fermentation of Carbohydrates

An interesting and characteristic property of the carbohydrates is that some of the sugars undergo fermentation with yeast. Fer mentation is a term used for the decomposition of carbohydrates brought about by the lower organisms of life, namely, the bacteria, the yeasts, and the molds. When glucose ferments ethyl alcohol is produced.

C<sub>6</sub>H<sub>12</sub>O<sub>6</sub> → 2 C<sub>2</sub>H<sub>5</sub>OH + 2 CO<sub>2</sub> Glucose Ethyl alcohol



Fig 2—Bacteria



Fig 3—Yeasts



Fig 4-Molds

All alcoholic beverages are the result of fermentation Each beverage is the result of fermentation of the particular sugars formed from the grain or present in the fruit by a microorganism especially adapted for the purpose. For instance wine spoils when a certain microorganism is present. Pasteur first observed that wines soured in certain wine growing districts in France. He finally found the germ which caused the wine to sour, a discovery which led him to search for organisms as a possible cause of human or animal diseases. By heating the wine to a temperature of 60° C, on three successive days, he was able to destroy the germs without changing the character of the wine. This method long since has been called "pasteurization," and is now employed for the commercial pasteurization of milk

Some fermentations produce acids, as when acetic acid is formed in the preparation of vinegar from apple juice, and commercial lactic acid from glucose, molasses or whey

$$\begin{split} & \text{Alcoholic fermentation} & \quad \text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2 \text{ C}_2\text{H}_5\text{OH} + 2 \text{ CO}_2 \\ & \text{Acetic fermentation} & \quad \text{C}_2\text{H}_5\text{OH} + \text{O}_2 \rightarrow \text{CH}_3\text{COOH} + \text{H}_2\text{O} \\ & \text{Lactic fermentation} & \quad \text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{CH}_3\text{-CHOH-COOH} \\ \end{split}$$

The disaccharides sucrose and maltose (lactose excepted) readily undergo alcoholic fermentation Lactose does not show alcoholic fermentation, but will undergo acid fermentation to yield lactic acid Acid fermentation of sucrose by a fungus is a commercial method of making citric acid

Since fermentative bacteria are always found in the intestines, there will be a certain amount of acids and gases produced therein during the course of digestion. If the amount becomes excessive, the acids and gases may cause digestive disturbances. This may be partially overcome by carefully regulating the carbohydrates in the duet.



Fig. 5—Fermentation tube

The yeast cell, which produces fermentation, contains an enzyme called zymase Actually zymase is a collection of enzymes Zymase acts only on monosaccharides, but yeast contains a second enzyme, invertase, which is capable of hydrolyzing the disaccharide cane sugar into glucose and fructose just as an acid may hydrolyze it,

thus preparing it for the action of zymase

The activity of the zymase is conditioned by the presence of a number of substances, notably phosphates and a complex substance called "cozymase"

Starch, a polysaccharide, cannot be fermented by yeast, but certain enzymes in plant cells, as diastase in sprouting grains, and enzymes (ptyalin, amylopsin) in the digestive juices, can change the starch into maltose. If the change from starch into maltose has been brought about by diastase, then maltase, a third enzyme of the yeast cell, can hydrolyze the maltose into glucose, which, in turn, can be fermented by zymase. Alcohol, then, may be considered as a product of the hydrolysis of starch into glucose, followed by the alcoholic fermentation of the glucose. It is from this source that a portion of the alcohol of commerce is obtained

# 4. Oxidation of Carbohydrates:

Sugars, sucrose\* excepted, readily undergo oxidation, the aldoses being easier to oxidize than the ketoses Oxidation first starts with the aldehyde group, then with the primary alcohol groups, and finally with the secondary alcoholic groups, eventually to form carbon dioxide and water Ketoses upon oxidation yield acids\*\* of lower molecular weights before finally being oxidized to carbon dioxide and water By the time the carbohydrates reach the body cells they are converted into glucose, C<sub>6</sub>H<sub>12</sub>O<sub>6</sub> Glucose easily undergoes oxidation to form carbon dioxide and water with the release of energy amounting to about four Calories per gram

There is no ash left, just the evolution of heat with the formation of carbon dioxide and water. Thus, the principal function of a carbohydrate in the body is to provide energy (about 1/6 of the calone intake). As this energy is not always needed at the instant, animals generally store it in the form of fat or glycogen, while plants store it in the form of carbohydrates. Starch then may be

The fact that sucrose and the polysacchandes in contrast to the other carbohydrates scarcely show any reducing properties is due to the linkage between the reducing groups (allehyde or ketone) of the monosacchandes composing them (p 327)

<sup>\*\*</sup> Fructose for example is supposed to undergo oxidation in the following manner

considered as a reserve supply of energy for plants. In animals carbohydrates are used almost as quickly as they are ingested, since they are quickly digested. In addition to the fact that carbo hydrates are the source of practically all of our energy (p. 497), they also are used to some extent for building body fat (p. 512) and proteins

The normal utilization of the carbohydrates takes place in the presence of invulin, an activating substance which is one of the hor mones. Insulin is secreted by the pancreas and a lack of this body regulator leads to diabetes. However, it is now suspected that im pairment of liver function is also a contributing factor in this disease.

### 5 React as Alcohols—Esterification

Because of the presence of hydroxyl groups carbohydrates will form ethers and salts and will esterify with acids. The most important ester from a biochemical viewpoint is that formed by glucose reacting with phosphoric acid. This substance in large part changes into lactic acid and then into glycogen with liberation of energy for body purposes (p. 508).

# 6 Reduction of Carbohydrates

The nonosuccharides and disaccharides (sucrose excepted) also undergo reduction with the absorption of energy and with the formation of products which the body uses to make into fat and other important substances. Just how the process goes on is not fully understood but we do know that it takes place since a carbo hydrate diet is fattening in 511).

### 7 Form Osazones

In addition to the chemical properties previously stated the monosaccharides and disaccharides (sucrose excepted) react with the base phenythydrazine C<sub>t</sub>H<sub>2</sub>NH NH<sub>2</sub> to form osazones in soluble compounds that vary in color, melting point and crystalline structure. The formation of osazones is a satisfactory method for the identification of a number of the sugars.

### SELF-TESTING QUESTIONS

- 9 What is the significance of glucose in the ur ne?
  10 Why does glucose react with Benedict s solution?
- 11 What are the advantages of Bened ct a solution over Fehling a solution?
- 12 How can you make a test to differentiate between glucose and milk sugar?

- 13. What is hydrolysis in organic chemistry?
- 14 What are the hydrolytic products in the digestion of sucrose, maltose, lactose, starch, and glycogen?
- 15. What produces fermentation?
- 16. What is formed during fermentation of glucose?
- 17. What other kind of fermentation is there besides alcoholic fermentation?
- 18 Explain how starch may be changed into alcohol.
- 19. What is the function of zymase, invertase, and maltase?
- 20. What is the principal function of a carbohydrate?
- 21. How much heat is liberated upon oxidizing one gram of glucose?
- 22 How are carbohydrates stored in animals? in plants?

The following table summarizes the characteristic properties of the important carbohydrates:

		Physical and Physio- logical Properties		Chemical Properties					
	Carbo- hydraie	Amount Soluble in 100 Gm of Water	Relative Sweet- ness Assuming Sucrose as 100	Dialyzes	Reduces Benedict s or Fehling's Solutions	Forms Yellow Osazones with Phenylhydra-	Ferments with Yeast	Gues Color with Iodine	Hydrolyzes to
haride	Glucose (dextrose)	80	74.3	+	+	+	+		
Monosaccharide	Fructose (levulose)	+	173 3	+	+	+	+		
Mc	Galactose	+	32 1	+	+	+	+	l	
de de	Sucrose (cane sugar)	198	100 0	+			+		Glucose + Fructose
Disaccharide	Lactose (milk sugar)	17	160	+	+	+			Glucose + Galactose
ñ	Maltose (malt sugar)	+	325	+	+	+	+		Glucose
	Starch	Colloidal						Blue	Glucose
Polysaccharide	Dextrina	Colloidal	Slight			+	Following action of diastase	No color, blue or red	Glucose
Polysac	Glycogen	Colloidal						Reddish brown	Glucoso
	Cellulose						By certam bacteria		Glucose

# III THE PRINCIPAL CARBOHYDRATES

### The Monosaccharides (Callings)

The monosaccharides are the basic constituents of all carbo hydrates Disaccharides and polysaccharides are made up of mono saccharide groups Not all monosaccharides (simple sugars) have nutritional significance, so we shall confine our study here to the three important hexoses as follows

Glucose (also called dextrose, grape sugar, or corn sugar)

Fructose (also called levulose, or fruit sugar)

Galactose

GLUCOSE (an aldose), from the dietary viewpoint is the most important of the monosaccharides since it is the principal form in which a carbohydrate reaches the tissues for oxidation. In the free state glucose is commonly present with fructose in fruits, especially in the juice of ripe grapes (20 to 30 per cent), and it is the main constituent of honey. As it is directly absorbable, glucose is adaptable to conditions of impaired digestion and is a valuable food for babies and children. Honey, containing about 40 per cent each of glucose and fructose quickly replaces in the blood and muscles the sugars that have been burned by stremuous exercise.



Analysis of Com	mercial Glucose
Water	18 48%
Dextrins	28 11%
Maltose	36 33%
Glucose	1678%
Protein	05%
Ash	25%

Fig. 6—Commercial Glucose. Commercial glucose represents a product of incomplete hydrolysis. Why do the manufacturers perfect to call this product corn syrup? Courtesy A. E. Staley Mira. Co.

Commercial glucose a mixture of glucose maltose and dextrin is obtained by the incomplete hydrolysis of corn starch (Fig 6). The starch is heated under pressure with dilute hydrochloric acd (0 6 per cent), which serves as a catalytic agent. At the end of the process the acid is neutralized the liquid is decolorized with bone black, and then concentrated to a thick syrup. Glucose is commonly known as corn syrup, a sweetening agent, much used in the prepara

$$(C_6H_{10}O_5)n + nH_2O \rightarrow nC_6H_{12}O_6$$
  
Starch Glucose

tion of jellies, table syrups, and candies 
Its sweetness is surpassed only by fructose and sucrose

Glucose (generally along with some sucrose) is also used to pre serve foods because it deprives fermentative bacteria of water by plasmolysis. The more concentrated the sugar solution, the greater will be the osmotic pressure, and the consequent added protection against the growth of the bacteria which spoil food by fermentation



Fig 7—Intravenous lafus on. Introducing a glucose and saline solution into the vein. What is the purpose of the thermometer suspended in the ant septic solution contained in the tall cylinder?

Corn syrup has become very popular as the carbohydrate used to modify cow s milk in infant feeding. In the hospital, highly refined glucose is used for intravenous infusions as a quick means of producing energy (Fig 7)

Glucose is found in the blood to the extent of about 0 1 per cent, although after meals this amount may be greatly increased, even so much that the blood cannot hold any more sugar (threshold point) In the latter case, glucose is excreted into the urine, causing a condition known as glycosuria Such a condition is not patho

logical, but is more of a protective device to keep the amount of sugar in the blood at a normal level Insulin is supposed to control the utilization of glucose, as explained later

Pure glucose is a crystalline solid, is fairly soluble (80 parts to 100 parts of water), and is sweet, but much less so than sucrose

FRUCTOSE (a ketose) is very similar to glucose in properties and it occurs, as does glucose, particularly in many fruits from which it gets the name of fruit sugar. On a commercial basis it is largely obtained by the hydrolysis of inulin, a polysaccharide found in the Jerusalem artichoke

Fructose is the sweetest of all of the common sugars Because of its sweetness (nearly twice that of sucrose), great solubility, difficulty to crystallize from solution, and its ability to absorb moisture and consequently not dry out by complete crystallization, fructose has a decided advantage over other sugars in candy making Such a sugar is useful in making chocolate centers, but the present price of fructose curtails its extensive use

GALACTOSE, another monosaccharide that is similar to glucose in its chemistry, is mentioned here because during digestion lactose (milk sugar) is hydrolyzed to glucose and galactose. Galactose is also formed from blood glucose by the mammary glands. The presence of a complex form of galactose in nerve and brain tissue would indicate an important use in infant feeding. Also it is used as a liver function testing agent.

### SELF-TESTING QUESTIONS

- 23 Why is glucose the most important monosaccharide?
- 24 Where 18 glucose found?
- 25 Why is honey considered a valuable food?
- 26 How is commercial glucose made?
  27 What is the hospital use of glucose?
- 28 What are the chief commercial uses of glucose?
- 29 What is glycosuria?
- 30 How does glucose compare in taste with cane sugar?
- 31 Enumerate four chemical properties of glucose
- 32 Why is galactose of biological interest?

# The Disaccharides (C12H22O11):

These sugars, built up from two monosaccharide molecules minus a molecule of water, are of biochemical importance as food sub stances. They are

Sucrose (cane, or beet sugar)

Lactose (milk sugar)

Maltose (malt sugar)



Fig. 8—Table Sugar. Sucrose or table sugar is the same substance whether obtained from sugar beets or sugar cane. What chemical changes are involved in photosynthesis to make plants stand between the race and starvation? Courlesy, Sugar Research Foundation Inc.

Sucrose: This is ordinary sugar, obtained generally from sugar cane and sugar beets, although it does occur to some extent in honey and in the sap (maple) and tissues of many of our common plants (carrots, beets, etc.)

The refining of ordinary sugar consists in filtering the juice, precipitating the albuminous material, neutralizing the acids in the juice, evaporating the filtrate to the concentration where crystallization takes place, and separating the crystals from the mother liquor or molasses. Molasses is an important source of commercial ethanol as it readily undergoes alcoholic fermentation with yeast.

If heated carefully sucrose may be melted, but an increase in temperature (about 200° C.) will partially decompose it into a brown amorphous substance called caramel. Caramel is much used as a flavor, as in making butterscotch pie, custards, or puddings. During caramelization at high temperature acrolein, an aldebyde, forms, which accounts for the sharp penetrating odor coming from

burned sugars spilled in a hot oven Some caramel is used as a coloring substance in such food preparations as gravy, vinegar, and synthetic vanilla extract Sucrose when boiled with water, and a small amount of an acid or an acid sall like cream of tartar to act as a catalytic agent, hydrolyzes according to the following equation.

The two sugars, glucose and fructose, collectively called invert sugar are used extensively in intravenous therapy Invert sugar is sweeter than sucrose, and crystallizes with difficulty in water Ad vantage of this latter property is taken in making fudge and butterscotch sauces for ice cream In a similar way boiling sucrose with vinegar prevents taffy from "going to sugar" Because of its hygroscopic power, invert sugar is useful in keeping foods moist, a property used in keeping frostings fondants, and other sugary coatings from drying out

The alcoholic groups ( -OH) of sucrose make possible the for mation of salts. For instance the filtrate from a 50 per cent solution of sucrose and a small amount of calcium hydroxide to form calcium sucrate finds a use in making cream while more easily

Sucrose may be distinguished from the monosaccharides, and the disaccharides lactose and maltose, by the fact that sucrose does not respond to the test for the carbonyl group (=C==0),  $\cdot$ e, it does not reduce Benedict's solution and does not form an osazone This insulative of sucrose to behave like an aldehyde or ketone sugar indicates that the characteristic properties of the aldehyde and ketone groupings have been destroyed in the union of the two molecules of hexose (p. 327) Sucrose, like glucose, undergoes al coholic fermentation with yeast \*

LACTOSE (MILK SUGAR) This sugar is present in the milk of all animals and during pregnancy it may be found in the urine. Cow's milk contains about 5 per cent of lectose, while human milk runs somewhat higher containing from 6 to 7 per cent. Lactose is not so sweet or so soluble in water as cane sugar. It is fortunate that lactose is less sweet than sucrose since this prevents milk from being nauseating and it also prevents babies from becoming accustomed.

<sup>\*</sup>The inverting enzymes first hydrolyze sucrose and then the zymase enzymes ferment the invert sugar

to having foods which are too sweet, a very important dietary measure when one wishes to make up a drink of high calorific con tent. The souring of milk is the result of the fermentation of lactose into lactic acid (lactic fermentation)

$$C_{12}H_{22}O_{11} + H_2O \rightarrow 4 CH_3 \cdot CHOH \cdot COOH$$
Lactose

Not only does lactic acid precipitate casein in milk, but the rennin in the stomach also precipitates casein. Casein precipitated from cow's or goat's milk by rennin is used in the making of cheese. The liquid left, called whey, contains the milk sugar. Lactose sugar does not ferment with pure yeast, nor is it very soluble. The fact that lactose does not ferment so easily as the other sugars would indicate another importance in infant feeding, since it would allow less chance for intestinal disturbances. The presence of lactic acid in the intestine checks the growth of putrefactive bacteria, and since both lactose and lactic acid are present in buttermilk, it may be understood why buttermilk and many similar commercial preparations are popular foods.

Upon hydrolysis in the intestines, lactose yields glucose and galactose. The digestive enzyme lactase is the catalyst

$$C_{12}H_{22}O_{11} + H_{2}O \rightarrow C_{6}H_{12}O_{6} + C_{6}H_{12}O_{6}$$

Maltose (Malt sugar) This sugar, especially abundant in germinating seeds, is formed from starch by the action of an enzyme, diastase, which exists in sprouting barley. An extract of sprouting barley, called malt extract produces maltose from starch In a similar way the enzyme ptyalin (salivary amylase) of the saliva and amylopsin (paincreatic amylase) of the paincreatic junces can change starch into maltose. Maltose, like lactose, is not so sweet as sucrose, and finds a wide use in making malted milk. With destrin if forms many valuable patented foods. In the body maltose is hydrolyzed by the enzyme maltase of the intestine into two molecules of glucose.

$$C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 + C_6H_{12}O_6$$

Maltose Glucose Glucose

Malt sugar readily ferments with yeast

### SELF-TESTING DUESTIONS

- 33 What are the sources of sucrose?
- 34 How is sucrose refined?
- 35 What is an important source of ethanol?
- 36 How is caramel made and for what is it used?
- 37 What is invert sugar and how does it differ in properties from sucrose?
- 38 How does sucrose differ from the monosaccharides and the other disaccharides in its chemical behavior?
  - 39 Why does not sucrose show reducing properties?
- 40 How does the percentage of lactose differ in cow and human milk? 41 Why can it be considered fortunate that lactose is not so sweet as
- enternoo?
- 42 In what two ways may casein be precipitated?
- 43 What are the hydrolysis products of sucrose and of lactose?
- 44 How is maltose made?

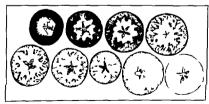
# The Polysaccharides (CaHiaOa)n

They include

Starches Dextrins

Glycogen (animal starch) Celluloses (vegetable fiber)

As a group (polysaccharoses), the polysaccharides are amorphous solids with little or no flavor, and they vary in their solubility and digestibility Like most compounds of high molecular weight, they



Fa 9—R pening of Fruit Changes Starch to Sugar As shown by the odine test apples which were picked too early (when too immature) show a heavy amount of starch in all but the core area. Why are apples picked at about the stage repre sented in apple four (top row count ng from the left)? Courtesy Div s on of Hort culture Central Experimental Farm Oltawa Canada

are not crystalline and form typical colloidal dispersions that are in capable of dialysis. Because of the absence of a free carbonyl group (=C=0) the polysaccharides, like the disaccharide sucrose, do not have reducing properties or form osazones

STARCH This is the principal form in which most plants store their food supply (potato 20 per cent, wheat 65 per cent, corn 65 per cent, rice 80 per cent) Starch is the cheapest, most plentiful and most important of our foods Fruits as apples and bananas contain starch when green, but when ripe the starch has been hydrolyzed to glucose with an accompanying sweet taste. At the same time there is an apparent decrease in pectin as evidenced by the fact that unripe fruits produce firmer jellies than ripe fruits. On the other hand the changes that occur in sweet corn and peas are the exact opposite of those changes that take place in unripe



fruits, ie, the sugar gradually changes to starch Starch grains under the microscope show concentric rings of cellulose between which is a semifluid polysaccharide which gives a blue color with iodine solution. During cooking the moist heat swells and ruptures the hard partitions, thereby allowing the semifluid portion to be partially dissolved and more easily digested I is for this reason that starchy foods are generally considered to be made more digestible by cooking. However, recent experiments have shown that all uncooked starches, potato starch excepted, digest as well as cooked starches, but that it takes longer to digest raw starches

In the mouth, starch can be changed by ptyalin into maltose and dextrins, but the greater part is hydrolyzed by amylopsin of the nancreatic truce to maltose, and then by maltase to glucose

Boiled starch in neutral or faintly acid solutions upon being cooled forms a colloidal gel (starch paste) which gives a blue color with indine solutions. The blue color vanishes on heating, but reappears on cooling. Boiling with dilute mineral acids gradually hydrolyzes starch to dextrin maltose, and glucose, while cold dilute acids slowly produce the "soluble starch" that is used for laundry purposes.

Yeast will not ferment starch. However, in bread making, diastase in the flour hydrolyzes some of the starch into maltose, which is changed by maltase of the yeast into glucose. The glucose is then fermented by zymase of the yeast into CO<sub>2</sub> and ethyl alcohol.

Starch | diatrase | Maltose | maltase | Sturch | Alcohol + Carbon dioxide | In four | In years | In years | In years |

Starch and the other polysaccharides, unlike the monosaccharides and disaccharides, do not dialyze.



Fig. 11—Starch Foods, Which food pictured here likely is richest in starch? Courtesy, National Dairy Council.

Dextrin This polysaccharide is a white amorphous substance formed by heating dry starch, and in a sense is a product inter mediate between starch and sugar. In solution, dextrin is slightly sweet, and, with iodine solution usually gives a violet to reddish brown color, the larger dextrin molecules (erythrodextrin) giving the darkest colors. The very simple dextrin molecules (achro odextrin) give no color change with iodine. During hydrolysis of starch by enzymes or acids there is a decrease in molecular weight, and the following color changes with iodine take place.

Bread crust and toast especially Melba toast, owe their sweetness to dextrin Since a solution of dextrin is sticky, it is often used as an adhesive. For example, the mucilage on the back of postage stamps is made of dextrin. In medicine, dextrin is used mainly for its adherence properties, and occasionally as an emulsifying agent (colloidal property). Also dextrin is used industrially to give smoothness to candy. The stickiness of corn syrup is mainly due to the dextrin present. Some dextrins slightly reduce Benedict's solution and all of them form osazones.

GLYCOGEN This is an animal starch, a carbohydrate reserve formed from blood sugar (p 514), and from a part of the protein and fat in the blood (pp 516 521 522)

Glycogen is present in all body cells particularly the muscle tissue and in the liver. Sometimes the liver contains as much as ten ounces of glycogen. That glycogen furnishes a reserve supply of energy needed by the tissues is shown by its rapid disappearance from the liver during sudden strain produced by fright or excess exercise.

$$(C_6H_{10}O_5)n + nH_2O \rightarrow nC_6H_{12}O_6$$
Shower

Glycogen is somewhat soluble (unlike starch), forms an opales cent solution in water, and with iodine solution gives a red to brown (port wine) color. It does not reduce Benedict's solution, nor does it ferment with yeast or form an osazone

Oysters and other shellfish contain as much as 9 per cent of glycogen and since liver always contains a large amount of gly cogen, both of these foods should be carefully considered in the low carbohydrate diet of diabetic patients

### SELF-TESTING QUESTIONS

45 How is starch digested?

46 What are the general properties of the polysaccharides?

47 What is the test for starch?

48 Why are starch foods cooked?

49 How is dextrin made?

50 What is the test for dextrin?

51 What are the medicinal uses of dextrin?
52 Where is glycogen found in the body?

53 From what is glycogen formed in the body?

# Physiological Uses of Cellulose

Industrially and economically cellulose is the most important carbohydrate. Although a polysaccharde it is not a nutrient for human consumption. It is the principal constituent of the cell walls of plants. Linen, cotton, hemp, and fiax are chiefly cellulose. Cellulose is insoluble in water, and because the body has no enzymes capable of producing its hydrolysis it is very indigestible. However, herbivorous animals are able to decompose and use it as a food. Older people often need to eat the soft cellulose present in vegetables as it gives bulk and causes peristalic action in the intestine. In this way it assists in preventing constipation. It is however, prohibited in spastic conditions of the intestines. A list of foods which help waste elimination is shown below.

IV. CELLULOSE

### FOODS WHICH HELP WASTE ELIMINATION

Apples	Cauliflower	Grapefruit	Pineapple
Apricots	Celery	Grapes	Plums
Asparagus	Cereals (whole grain	Honey	Prunes
Beets	preparations)	Lettuce	Radishes
Bran	Cranberries	Maltose	Raisins
Bread (bran whole-	Cucumbers	Olive oil	Rutabagas
wheat graham)	Currants	Olives	Spinach and other
Brussels sprouts	Dates	Ontons	greens
Buttermilk (vogurt	Endive	Oranges	Strawberries
or acidophilus)	Figs	Parsnips	Tomatoes
Cabbage	Fruit juices jellies	Peaches	Turnips
Cantaloupe	OT ICES	Pears	Watermelon
Carrots			

NOTE Substances indicated by stalic type are especially valuable for their minerals.

When treated with a strong hydrolytic agent such as dilute sulfuric acid, cellulose yields glucose. It is for this reason that cotton goods are weakened by acids, as well as by alkalies (washing powders, soap). Although cellulose is the main product formed during the growth of plants, there are also present intermediate products, called hemicelluloses, which differ from the normal cellulose by being more readily hydrolyzed. The hydrolysis of hemicelluloses takes place very readily in the presence of an alkali, and explains why the addition of baking soda is more likely to soften young vegetables or fruits than old ones. Such an addition how ever may result in the destruction of vitamins. Cellulose differs from the other polysaccharides discussed by giving no color change with jodine.

AGAR AGAR This is a polysaccharide found in seaweed, and is of interest on account of its use in preparing solid culture media in binteriology Hydrolysis of agar agar produces galactose Agar agar has little food value but when used medicinally it adsorbs large quantities of water, and for this reason is used to give bulk to the feces in order to overcome constipation

Note The remainder of this chapter may be amitted where time must be saved

# Commercial Uses of Cellulose:

Through chemical changes a large number of valuable products are made from cellulose, the most important of which follow

CELLULOSE NITRATE (NITROCELLULOSE) Since cellulose has adolonlog groups in its molecule it can react with acids to form esters, the most important of which are the nitrates and the acetates Thus cellulose with nitric acid forms cellulose nitrate (pyroxylin), or, if three nitrate groups are substituted for as many hydroxyl groups gun cotton is formed A solution of cellulose nitrate forms a transparent film. It is this property that makes nitrate forms cellulose suitable for preparing collodion, cellophane, celluloid, and certain lacquers. The higher nitrated forms are used for explosives. Pyroxylin used on certain fabrics makes artificial leather.

CELLULOSE ACETATE In decided contrast to cellulose nitrate, the ester cellulose acetate is nonexplosive and burns very slowly with the production of nontoxic furnes. As a consequence, cellulose acetate finds an extensive use in the manufacture of "safety" (slow-burning) motion picture films, x-ray films, and "acetate" fabrics (Celanese).

MERCERIZED COTTON: When cotton cloth (cellulose) is treated with sodium hydroxide it shrinks and becomes tougher, and if the goods is under tension when thus treated, it will have a silky ap-

pearance. This material is called mercerized cotton.

RAYON: Cellulose, as wood fiber, when treated with sodium hydroxide, reacts with carbon disulfide, and yields cellulose xantate, a yellow solid which readly dissolves in the sodium hydroxide solution to form water-soluble viscose Upon forcing the heavy, yellow solution of vicose through minute tubes into dilute sulfluric acid, coagulation takes place with the formation of fine threads differing in composition but having a sheen somewhat like that of real silk. The manufactured cloth, called rayon, formerly was known as artificial silk.

CELLOPHANE: A cellulose product of great importance is cellophane, which is extensively used as a transparent wrapping material. The manufacture of cellophane differs from that of rayon



Fig. 12—Applying the Suture. Nylon, a synthetic fiber made from ecol, air, and water, has a strength equal to silk, is elastic, and is insensitive to moisture. Why are nylon fibers suitable for surgical sutures? Courtery, Bauer and Black

mainly in that the viscose is forced through a narrow slit and forms a sheet instead of a thread

PAPER Large quantities of cellulose such as fibers, and the cheaper grades of wood are used in the manufacture of paper Linen and rag papers are no longer manufactured in quantity

ETHYL CELLULOSE, CARBOXYMETHYLCELLULOSE In addition to cellulose showing the behavior of an alcohol in forming esters and cellulose xanthate, it will form ethers One important ether is ethyl cellulose, a compound much used in paper sizing, printing inks, certain soaps, synthetic resins, and in adhesives Another compound, carboxymethylcellulose (CMC). has similar uses

### SELE-TESTING QUESTIONS

- 54 Why does cellulose form esters?
- 55 Name two important esters of cellulose
- 56 What property of the low mitrates of cellulose makes them suitable for making collodion cellophane, and certain lacquers?
- 57 What is artificial leather?
- 58 What are the advantages of cellulose acetate over cellulose natrate in motion picture films?
- 59 How is mercerized cotton made and how does it differ in properties from ordinary cotton?
- 60 How is rayon made?
- 61 From what can paper be made?

### SUGGESTED ACTIVITIES

- I THOUGHT-PROVOKING QUESTIONS
  - 1 What is the initial source of all carbohydrates?
  - 2 Discuss the possible various uses of saccharine
  - 3 How can you suggest a partial elimination of intestinal fermentation?
  - 4 In what way is knowledge of the pH value of commercial glucose (corn syrup) of great importance in the manufacture of crystal line candies?
  - 5 Why is maltose considered to be a valuable food for infant feeding?
  - 6 When the skin of bananas shows signs of darkening why are the bananas considered more digestible?
  - 7 Discuss the usefulness of fermentation in the home and in industry 8 Account for the fact that a teaspoonful of vinegar beaten into boiled
    - frosting when flavoring is added will keep the frosting from being brittle and breaking when cut
  - 9 How do you account for the use of cream of tartar in making for dant (a kind of candy)? The use of starch in corn starch pud dings?
  - 10 How may you account for agar, a dried gel being used like cellulose to relieve constipation?

- 11 As the carbohydrate molecules become larger and more complex in structure how are their properties changed?
- 12 How may the sweet taste of a solution containing sucrose be in creased?
- 13 Why is it that young veretables but not old ones, can be made more tender by boiling in the presence of baking soda?
- 14 Compare and contrast in tabular form the properties of the poly saccharides, paying particular attention to taste, solubility, hydrolysis, and the iodine test
- 15 What are the medicinal values of lactore?
- 16 How does the digestion of the disaccharides and polysaccharides by enzymes differ from hydrolysis produced by dilute nonoxidizing acida?
- II VOCABULARY TESTING OF NEW TERMS carbohydrate disaccharide

sacchande polysaccharide monosaccharide

fermentation alimentary glycosuria hydrolysis

aldoce ketnee asymmetric hemicellulose

- III TOPICS FOR ORAL OR WRITTEN REPORTS
  - 1 Industrial Hees for Cellulose 2 Insulin to the Rescue of the Diabetic

  - 3 Sugars in Nutrition
  - 4 Natural Fibers vs Synthetic Fibers

### LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on page 720

# ANIMAL AND VEGETABLE FATS AND OILS

### CHAPTER OUTLINE

- I FATS AND OILS
  (a) General remarks
- (h) Occurrence of fats and oils
- II COMPOSITION AND NATURE
  (a) Glycerides of fatty scids
  - (b) Consistency of fats
    (c) Hydrogenation of fats
- III PROPERTIES OF PATS
  - (a) Physical properties

    1 Greasy feeling
    - 2 Color
    - 3 Melting point 4 Specific gravity
    - 4 Specific gravit 5 Solubility
    - 5 Solubility 6 Emulsification

- (b) Chemical properties 1 Hydrolyze
  - 2 Saponify Soap Varieties of soap
    - Hymolal salts
      3 Assume a rancidity
- 4 Decompose when heated 5 Undergo oxidation
- IV PHYSIOLOGICAL IMPORTANCE OF PATS
  - (a) Function in the body (b) Behavior in the body
  - (c) Assimilation of fats
  - V OTHER LIPIDS

    (a) Some complex and derived lipids

# I. FATS AND OILS

### General Remarks:

The animal and vegetable fats and oils make up a major division of a class of compounds of natural occurrence called lipids The following classification has been suggested

- Simple lipids These are esters of the fatty acids with various alcohols (a) Animal and vegetable fats and oils (b) Waxes
- (2) Complex or compound lipids Made up of esters of fatty acids which contain groups in addition to those found in the simple lipids (a) Phospholipids (b) Glycolipids
- (3) Derived lipids Hydrolytic products formed from simple and complex lipids (a) Sterols (b) High molecular weight fatty acids

The lipids have the common characteristic of water insolubility. They are, however, soluble in the so called fat solvents of which ether, chloroform, and carbon tetrachloride are representative.

The major portion of this chapter is devoted to a study of those simple lipids which are known collectively as the animal and vege table fats and oils These constitute one of the three major classes of foodstuffs

### Occurrence of Fats and Oils:

Fats are widely distributed among both the animals and plants. In animal organisms, especially in the higher animals, fats are found in all tissues, between the muscles, around all organs, in bone marrow (96 per cent) and in very large amounts in adipose (fatty) tissue that is directly under the skin.

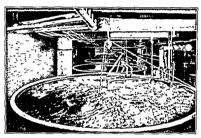


Fig. 1—A Seething Mass of Soap. Soap in the making Does any form of soap appear in digeston? Courtesy, Swift & Company.

Tallow from cattle, sheep, and horses; lard from the fat surrounding the interior parts of the body (entrails); suet or the hard fat particularly about the kidneys; and butter from milk are our most important animal fats. In plant organisms, liquid fats called "oils" are found in the seeds (embryo), roots, and fruits. Vegetable fats occur in abundance in cottonseed oil (Wesson), linseed oil, palm oil, olive oil, coconut oil, peanut oil, corn oil (Mazola), and many others. The seeds of cereals are usually low in fat content since starch takes the place of fat in the composition of such seeds.

Vegetable fats (mostly soybean, cottonseed, coconut, and peanut oils) are used for preparing butter substitutes, called margarines. Following hydrogenation (p 355) the fats are churned with pasteurized, skimmed milk. Addition of butter flavor (butyrin), vitamins A and D, salt and coloring dye gives a food which compares



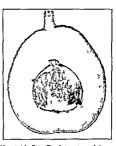


Fig 2—Avocado Fruit is a R.ch Source of Vegetable Fat. The fat content of the avocado is as high as 50 per cent. How does the avocado compare in calonic value with other fruits? Courtesy Arg cultural Experiment Stat on University of Florda.

well with butter in odor, taste and food value Today the production of oleomargarines exceeds that of butter

# II. COMPOSITION AND NATURE OF FATS

Fats contain the same three elements as carbohydrates, namely, carbon hydrogen and oxygen However, the hydrogen and oxygen are not present in the same proportion as in water, and the relative amount of oxygen in fats is much smaller than that occurring in carbohydrates. The significance of this relatively small amount of oxygen is pointed out later.

# Glycerides of Fatty Acids

It may be recalled that an ester is the result of an alcohol reacting with an acid

Fats are also esters and may be considered to have been formed by glycerol, an alcohol reacting with fatty acids of high molecular weight. The formula  $C_3H_5(OH)_3$ , for glycerol shows that three hydroxyl groups may function in the formation of a fat, and since

the fatty acids are monobasic, that is, each acid contains one carboxyl group, —COOH, it follows that one molecule of glycerol will require three molecules of fatty acid to form a natural fat. If we use R as the general symbol for the hydrocarbon radical or residue, and use the formula R · COOH to represent any monobasic acid, the relationship between glycerol and the fatty acids to form fats may be shown by the following equation,

In the simple glycerides (esters of glycerol) the three fatty acid residues are the same. If two or three kinds of fatty acid residues are present the glyceride is termed mixed

In illustrating the general chemical characteristics of fats it is a practice to use the simple glyceride structure. However, it is to be noted that for the most part the natural animal fats and vegetable oils are mutures of mixed glycerides.

The fatty acids which are most frequently found in the glycerides of fats and oils are butyric, palmitic, stearic, and oleic acids. The formulas for these acids and their glyceryl esters are included in the following table.

<sup>\*</sup> Evidence for this type of cleavage in contrast to the usual behavior of acids has resulted from the use of the beavy isotope of oxygen as a tagged atom

# FATS DERIVATIVES OF GLYCEROL AND FATTY ACIDS TYPE FORMULA, C<sub>3</sub>H<sub>5</sub>(OOC R)<sub>3</sub>

Futty Acid	Formula of Fatty Acid	Formula of Ester	Name of Fat	Occur rence of Fat
Satu rated	CaH2aO2 Series			
Butyric	C₃H7COOH	C <sub>3</sub> H <sub>1</sub> (OOC C <sub>3</sub> H <sub>7</sub> ) <sub>3</sub>	Glyceryl bu tyrate or bu tyrin*	Butter
Palmitic	C15H31COOH	C <sub>3</sub> H <sub>4</sub> (OOC C <sub>15</sub> H <sub>31</sub> ) <sub>3</sub>	Glyceryl pal mitate or palmitin	Palm oil lard
Stearic	C17H35COOH	C <sub>3</sub> H <sub>5</sub> (OOC C <sub>17</sub> H <sub>35</sub> ) <sub>3</sub>		Tallow
Unsatu				
rated	C.H2n-2O2Series			İ
Oleic	(one double bond) C <sub>17</sub> H <sub>32</sub> COOH	C <sub>3</sub> H <sub>6</sub> (OOC C <sub>17</sub> H <sub>23</sub> ) <sub>3</sub>	Glyceryl ole ate or olem	Olive
Linoleic	C <sub>8</sub> H <sub>2</sub> ,-4O <sub>2</sub> Series (two double bonds) C <sub>17</sub> H <sub>31</sub> COOH	C <sub>3</sub> H <sub>5</sub> (OOC C <sub>17</sub> H <sub>31</sub> ) <sub>3</sub>	Glyceryl lino leate or linolein	Corn oil
Linolenic	C <sub>4</sub> H <sub>2.</sub> sO <sub>2</sub> (three double bonds)	C <sub>3</sub> H <sub>5</sub> (OOC <sub>17</sub> H <sub>29</sub> ) <sub>3</sub>	Glyceryl lino lenate	Linseed oil

<sup>•</sup> The name of the ester is derived from the name of its acid by using the suffix in for the final ic of the acid

Some additional unsaturated fatty acids of interest are linoleic acid in cod liver oil, ricinoleic acid in castor oil, and chaulmoogric acid, a cyclic fatty acid, in chaulmoogra oil. The ethyl ester of the latter acid was formerly used in the treatment of leprosy

# Consistency of Fats:

All natural fats are mixtures of glyceryl esters, and their consistency depends largely upon the various glycerides that are present For instance, olein, the glyceride of unsaturated oleic acid, is a liquid to  $-6^{\circ}$  C, while palmitin and stearin, the glycerides of saturated fatty acids, are solids up to  $65\,5^{\circ}$  C and  $71\,6^{\circ}$  C respectively In other words, saturated fats are solids

The difference in the relative amount of ofem (unsaturated fat) will determine whether a fat is a solid, semisolid, or a liquid (oul\*) at ordinary temperatures. Thus olive oil with about 95 per cent olein is a liquid, while animal fats with less olein and a larger percentage of the saturated fats, palmitin and stearin, are solids. Mutton fat has a little olein, beef fat somewhat more, while pork fat contains considerable olein (65 per cent) and is of a much greasier consistency (Fig. 3). It is due to the relatively high amount



Fig 3—Fat in Ham and Bacon. Why is pork fat greasser than most animal fats? Courtesy, U S Dept of Agriculture

of olein that the fat of cold blooded animals remains fluid at temperatures at which the fat of warm-blooded animals solidifies. Human fat with 70 to 80 per cent of olein, about 15 per cent of palmitin, and 5 per cent of stearin melts between 20° C. and 25° C., and consequently is always a liquid at body temperature (37° C.).

### Hydrogenation of Fats:

From the previous paragraph, it is evident that at ordinary temperatures (20° C.) vegetable fats contain a larger proportion of clein, and are in the liquid state, while animal fats with less of the clein and more of the palmitin and stearm are solids. By comparing the formulas of stearic acid and cleic acid or their esters, it is noticeable that clein differs from stearin by containing six less hydrogen atoms per molecule, and that cleic acid has two less

<sup>•</sup> In general, the word oil refers to any greasy feeing substance such as he natural fats as well as to substances not chemically related to the natural fats, such as mixtures of hydrocarbons (mineral oils), and to cycle compounds of plant origin (oil of wintergreen, oil of femon). It is customary to use the term fat when the substance is a sold at 20°C, and if a liquid at that temperature to regard it as as no il.

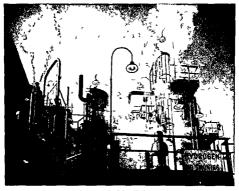


Fig 4—Hydrogenation of Vegetable Oils. Hydrogenation changes cottonseed oil into Crisco, and coconit and peanut oil into butter substitutes (aut margarines) What makes this reaction possible? Courtesy, Practer & Gamble Co

Acids	Ester
Stearic, C <sub>17</sub> H <sub>35</sub> · COOH	Stearin, C <sub>3</sub> H <sub>5</sub> (OOC · C <sub>17</sub> H <sub>35</sub> ) <sub>3</sub>
Oleic, C <sub>17</sub> H <sub>35</sub> · COOH	Olem, C <sub>3</sub> H <sub>5</sub> (OOC · C <sub>17</sub> H <sub>55</sub> ) <sub>8</sub>

hydrogen atoms than steara acid. A similar difference of two less hydrogen atoms between ethane C<sub>2</sub>H<sub>4</sub> and ethylene C<sub>2</sub>H<sub>4</sub> we explained (p. 270) by assuming that the carbon atoms in ethylene have a double bond between them This implies then that olein, like ethylene, is an unsaturated compound, that it contains a double bond, and is therefore capable of forming addition products From this it is possible to understand how the addition of hydrogen atoms may convert hquid fats (unsaturated) into solid fats (saturated). Such a change of olein to stearin is accomplished by heating olein under pressure (225 lbs at 180° C.) with hydrogen in the presence of a catalyst (finely divided nickel).

Hardening of an oil  $C_3H_5(OOCC_{17}H_{33})_3 + 3 H_2 \longrightarrow C_3H_5(OOCC_{17}H_{35})_3$ Olein (M.P =  $-6^\circ$ )

Unsuburated for (final d)

Solvering for (fold)

This reaction, known as hydrogenation, makes possible the manufacture of edible lard substitutes such as Crisco and Spry from cottonseed oil and other vegetable oils. The hydrogenated oils are particularly well adapted for deep fat frying. In the commercial hydrogenation of vegetable oils not all of the unsaturated content is converted to saturated, to do this would give a product too hard and brittle for use as a shortening in cooking. Today's shortenings are hydrogenated only sufficiently to eliminate the more highly unsaturated molecules which are responsible for poor keeping quality. Hence the resultant product, a soft solid, contains a considerable proportion of unsaturated glyceride.

It is because of unsaturation that certain fats absorb odors Lard, for example, quickly absorbs an odor from frying fish, and butter absorbs odors from bananas and omons. This property of

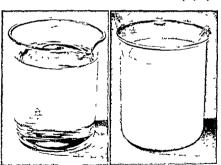


Fig. 5—Hydrogenation. The hydrogenation of the vegetable all pictured on the left gives the soft solid shown on the right. Does this solid contain any un saturates? Courlesy, Procter & Gamble Co.

absorption on the part of unsaturated fats is used to commercial advantage in extracting valuable perfumes, as rose oil from roses

In general it is to be remembered that unsaturated fats, in con trast to the saturated ones, are liquids. Like the unsaturated hydrocarbons the unsaturated glycerides form addition products at the double bonds, the most important of these being the addition of hydrogen

### SELF-TESTING QUESTIONS

- 1 What is the principal function of a fat?
- 2 Where are the fats found in animals and in plants?
- 3 Name four important animal fats
- 4 How is oleomargarine made?
- 5 What is a fat chemically?
- 6 Name the three most common fatty acids entering into the composition of natural fats
  - 7 How do you account for the difference in the consistency of fats?
  - 8 Why are some fats greasier than others?
- 9 How do the fats of the cold blooded animals differ from those of warm blooded animals in composition?
- 10 What is an unsaturated fat?
- 11 How is hydrogenation accomplished? What is the advantage of hydrogenation?

## III. PROPERTIES OF FATS

# Physical Properties of Fats:

Even though fats vary in their consistency they bear a much closer resemblance to each other in their physical properties than they do in their chemical behavior. As a group, they show the following similarities

GREAST FEELING Fats are characterized by having a slippery, greasy feeling, and when in contact with many substances, penetrate them and produce grease spots On paper, a grease spot becomes translucent, which serves as a simple physical test for a fat

Color Fats and oils when pure are colorless, odorless, and taste less, but when obtained in the natural form they may range in color from a yellow to a red Natural oils generally are of a yellowsh color because of the presence of a yellow fat soluble pigment. How ever, some vegetable oils, like olive oil, may have a green color due to the presence of the green pigment chlorophyll. Natural fats impart flavor to foods and make them more palatable. The taste of butter is in part due to the compounds produced by bacteria during the presence of the green pigment.

MELTING POINT Since a fat is a mixture of glycerides of different fatty acids the melting point is not very sharp a low melting point indicating the presence of glycerides of unsaturated fatty acids

Specific Gravity Fats are lighter than water, their specific gravity being fairly uniform (0.86) in solid fats, but showing a greater variation in liquid fats (0.91 to 0.94)

Solubility With such a small amount of oxygen in proportion to the large amount of carbon and hydrogen, fats closely resemble the higher hydrocarbons in their waxy nature, solublity, and in activity. The most characteristic physical property of those fats formed from the higher fatty acids is that they are readily soluble in ether, chloroform, carbon tetrachloride, gasoline, and boiling alcohol, but are insoluble in water. However, butyrin and other glycendes of the lower fatty acids are very slightly soluble in water. Fats are also soluble in each other. Of the fat solvents used for removing grease stains carbon tetrachloride (Carbona) and trichloroethyleme are the safest since they are not flammable (p. 278).

EMULSIFICATION With water, fats give an emulsion only after vigorous and prolonged shaking. The emulsion, however, is only temporary unless some colloidal substance such as soap, destrin, or albumin is present. Then the colloids form a film on the surface of the tiny, dispersed fat globules and prevent them from running together to form larger globules of fat that ordinarily would separate out on top of water. An emulsion of oil suspended in this way in water has a milky appearance. Emulsification of fats in the in testines, a very important function of the bile, is of the greatest physiological importance since only in that condition are fats digested in the intestines. Furthermore, the fat that is carried by the blood to the cells is in the form of an emulsion.

# Chemical Properties of Fats:

Although the chemical properties of the fats are few, still they are of decided interest and importance as may be noticed from the following.

1 FATS HYDROLYZE The most important and characteristic reaction of fats is hydrolysis, since by this reaction fats are split up again into glycerol and fatty acids

 $C_2H_5(OOC \cdot C_{17}H_{35})_3 + 3 HOH \rightarrow C_3H_5(OH)_3 + 3 C_{17}H_{35}$  COOH

For Steam Glycerol Insoluble fatty acid

This reaction is important because all fats in the course of digestion

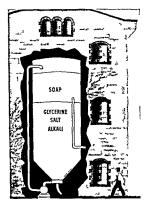


Fig 6—A three story soap kettle where 150 tons of fats o is and soda are boiled at a time. The glycer ne drawn off at the bottom has what important uses in the hosp tal? Courtesy Procter & Gomble Co

go through this same change (p 370) In the body, hydrolysis of fats is accomplished by enzymes, especially steapsin (pancreatic linase)

2 FATS SAPONIFY If in place of water in the foregoing equation an inorganic base, as NaOH, is heated with a fat glycerol and the metallic salt of a fatty acid are formed

$$C_3H_5(OOC C_{17}H_{35})_3 + 3 NaOH \rightarrow C_3H_5(OH)_3 + 3 C_{17}H_{35}COONa$$
For Glycerol Metall'c soft (soop)

The metallic salt is a soap, and the process of reacting a fat with an alkali to form a soap is called saponification. In this reaction of fats it is believed that the base first catalyzes hydrolysis and then reacts with the insoluble fatty acids formed to make soap

Soap Soap was first made by boiling fats of animals with the alkaline substance extracted from the ashes of wood. If the alkali

used in soap making is sodium hydroxide solid or hard soaps are formed, but if potassium hydroxide is used, semiliquid or soft soaps are made. Only these two metallic soaps are soluble in water and hence are the only ones that have any practical value in making lather for cleansing purposes. The glycerol formed in the preparation of soap is left in many commercial soaps as it has beneficial action on the skin and makes the soap transparent. However, dissolved soap (colloid) may be salted out from a soap solution by adding common salt, and the glycerol separated from the spent lye solution by distillation with steam. This precipitating action of salt water helps us understand one of the difficulties in obtaining a lather with sea water. On the other hand, when a soluble soap is used in hard water a chemical reaction takes place between the soluble soap and the minerals (p. 82) in the water to form an in soluble curdy precipitate of calcium and magnesium soap

2 
$$C_{17}H_{35}COONa$$
 +  $Ca^{++}$ ,  $SO_4- \rightarrow 2$   $Na^+$   $SO_4-$  +  $(C_{17}H_{35}COO)_2Ca$ 
Solvble scap

Mineral Insolvble scap

Since soap is used up in precipitating the calcium ions, a suds will not form until the calcium ions are removed. This explains why hard water is first softened by the addition of some cheap softening agent, such as washing soda (sodium carbonate), trisodium phosphate, or borax (p. 84). The calcium or magnesium ions are precipitated as insoluble carbonates, phosphates, or borates.

$$2Na^+$$
,  $CO_3^- + Ca^{++}$ ,  $5O_4^- \rightarrow 2Na^+$ ,  $5O_4^- + CaCO_3 \downarrow$ 

If sufficient soap is used, hard water will become soft, but as a softening agent soap is expensive. A further difficulty with hard water is that the sticky precipitate of insoluble soaps adheres to objects and is difficult to remove.

#### Varieties of Soap

Scouring Soaps These are largely abrasive material, as fine sand purnice and infusorial earth held together by about 10 per cent of soap

Green Soap This soap used in the hospitals is a soluble soft soap in alcohol, molded and dried

soap in account, moneted and united Germicidal or Medicaded Soaps. These types (carbolic, Lysol, mercuric chloride) frequently have an irritating effect on the skin, and it is questionable whether they are as serviceable as claimed Soaps containing hexachlorophene (Gamophen, Dysept pHisohex)



Fig 7—The Scrub Up To prevent infection strict asepsis must be practiced in hospitals. One drop of soap to one thousand drops of water will kill germs which cause many diseases. What are some of these diseases? Courtesy Monsonlo Magazine Monsonlo Chem cal Company

are ganing in popularity as surgical scrub up soaps and toilet soaps, because they not only have pronounced bactericidal effects, but also are nomiritating. Ordinary father made in washing the hands with any soap has considerable germicidal properties, as the lather itself is quite effective against all germs except the typhoid germ and the staphylococcus organism.

<sup>\*</sup>The permicial action of scape on such organisms as the streptococcus meningono cus genoecoccus pneumococcus choicer and diphthera hacillus as due primarily to the colloidal properties of the scap the ability of the scap solution to lower surface ten soon the temperature of the scap solution the absence of the foreign material (albu minous) which interferes with the germicidal action the diffusible or dialyzing power and the fairly acids present I uning sogn in pure water the soap first dissolves and then partially hydrolyzes. Disso F A, Germicidal Value of Pure Scap Medical Review of Reviews Au; 1954

In using soap in pure water the soap first dissolves and then partially hydrolyzes

C<sub>17</sub>H<sub>36</sub>COONa + HOH 

NaOH + C<sub>17</sub>H<sub>36</sub>COOH

Seep Involuble
fatty acid

The fatty acids do not precipitate but stay in a colloidal condition Soap solution, then, is really an alkaline colloidal dispersion and its



Fig. 8—Testing Soop Effect on Skin. Women here sook their left arms in one soop solution and right arms in a second soop solution. After a measured interval the forearms and hands are examined to compare the effect of various soops and the skin. Why are some soops fir tating to the skin? Courtesy Practice & Gamble Co.

cleansing power is due to the fact that when soap is rubbed upon the skin or other surfaces the colloidal particles pick up (adsorb) the dirt, and transfer it to the films that surround the air bubbles which compose the suds or foam Any oily substances present are broken up by the rubbing to form minute droplets that become surrounded with films of soap to form a stable emulsion which is washed away The cleansing power of a soap suspension is due to its adsorbing and emulsifying powers. The most important use of soan is to wash and vet not irritate the skin. Good hand soans contain no free alkali to irritate the skin, the word "free" meaning any excess sodium hydroxide not used in the saponification However, many cheaply made soaps contain sufficient free alkali to irritate the skin and to have a deteriorating effect upon silk, wool, and linen Another point to remember is that the price paid for a soap does not guarantee its quality, since price depends to some degree upon the perfume and pigments added. Some of our cheap toilet soaps with no color or perfume may be even better than some of the more expensive brands

Floating Soaps. These contain air beaten into them while in a pasty condition

Washing Powders These powders contain the water softeners (trisodium phosphate, sodium earbonate, borax, or sodium hexa metaphosphate) and soap The mixture is melted, dried, and then pulverized

Yellow Laundry Soap This type of soap usually contains the "filler" rosin, and an excess of sodium hydroxide (lye), a very un desirable ingredient in hand soaps Such soaps have strong cleans ing properties

Zinc Stearate This insoluble soap is a white dusting powder of importance for babies in that it has antiseptic properties and does not adsorb water like other powders do However, since the dust of zinc stearate is irritating to the mucous membranes, care should be exercised when using it

Another Type of Detergent (Hymolal Salts) Research in applied chemistry has produced a new type of detergent (Dreft, Drene) from higher alcohols, sulfuric acid, and caustic soda. The interesting thing about these salts is that they overcome two basic weaknesses of soap by not forming insoluble salts with calcium, magnesium or iron ions, and not leaving a soap film on clothes or dishes being washed. They produce an excellent lather even in hard



Fig. 9.—Synthetic detergent at left produces suds in hard water while ordinary soap at the right forms insoluble curds. The value of detergents is limited to what two main facts? Courtery, Du Pant Ca.

water.\* For this reason these detergents are used in dentifices and shampoos, and because they do not form alkaline solutions as do soaps they are fine for washing delicate fabrics which ordinarily might be injured by soap.

3. FATS BECOME RANCID: Upon long exposure to air, many unsaturated fats turn yellow, acquire an unpleasant taste, and develop free fatty acids to become rancid, a general term referring to any

2 CH<sub>2</sub>(CH<sub>2</sub>)<sub>10</sub>CH<sub>2</sub>NaSO<sub>4</sub> + Ca(HCO<sub>2</sub>)<sub>2</sub> = (CH<sub>2</sub>(CH<sub>2</sub>)<sub>10</sub>CH<sub>2</sub>SO<sub>4</sub>)<sub>2</sub>Ca + 2 NaHCO<sub>3</sub> Sodium lauryl sulfate Calcium Calcium lauryl Sodium bicarbonate sulfate bicarbonate

<sup>\*</sup> These new detergents, called hymolal salts, are made as follows-

I. Hydrogenating a fatty acid as lauric acid from eccoanut oil into an alcohol
 CH<sub>3</sub>(CH<sub>2</sub>)<sub>10</sub>·COOH + 2 H<sub>2</sub> → CH<sub>3</sub>(CH<sub>2</sub>)<sub>10</sub>CH<sub>2</sub>OH + H<sub>2</sub>O

 II. Sulfonating the alcohol into an acid sulfate.

CH<sub>3</sub>(CH<sub>2</sub>)<sub>10</sub>CH<sub>2</sub>OH + H<sub>2</sub>SO<sub>4</sub> → CH<sub>3</sub>(CH<sub>2</sub>)<sub>10</sub>CH<sub>2</sub>HSO<sub>4</sub> + H<sub>2</sub>O III. Neutralizing the acid sulfate to a neutral sodium salt

CH<sub>3</sub>(CH<sub>2</sub>)<sub>10</sub>CH<sub>2</sub>HSO<sub>4</sub> + NaOH → CH<sub>2</sub>(CH<sub>2</sub>)<sub>10</sub>CH<sub>2</sub>NaSO<sub>4</sub> + H<sub>2</sub>O
In hard water solution a soluble calcium salt is formed

objectionable odor or taste. This rancidity is the result of a hydrolytic change with the production of unpleasant smelling volatile fatty acids, and of the exidation of unsaturated fatty acids with the formation of volatile aldehydes, shorter chained acids, and ketones Rancidity, as in butter, not only may be due to exposure to air with the development of buttpic acid, but also may be due to bacterial action upon impurities present. Since many foods such as bacon, cookies, peanuts, and potato chips are rich in fats, it becomes im portant to know how to prevent fats from becoming rancid. Experiment has shown that the acid formed during hydrolysis tends to act as a catalyzer in speeding up the reaction, also that the catalytic action of enzymes present is affected by temperature. Since both hydrolysis and enzyme action are relatively decreased by lowering the temperature, fats and foods rich in fat should be kept in a cool condition.

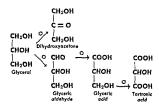
4 FATS DECOMPOSE WHEN HEATED—ACROLEIN TEST When fats are strongly heated (300° C), either alone, as in frying, or in the presence of a dehydrating agent like potassium hydrogen sulfate, they undergo hydrolysis The glycerol which is released then undergoes dehydration to form acrolein, an unsaturated aldehyde

The presence of acrolem is recognized by its irritating effect on the mucous membranes of the eyes, nose, and throat, and by its acrid odor where grease has caught fire, or when meats have been broiled or roasted at too high a temperature

As the glyceryl radical is a part of all common fats, this forma tion of acroleum may be used as a standard chemical test for fats and glycerol

5 Fats Undergo Oxidation Fats are composed of hydrogen, carbon, and oxygen and like the carbohydrates yield carbon dioxide and water when completely oxidized Since glycerol is a common constituent of all fats, and is a trihydric alcohol, the oxidation reactions of fats and oils show all the chemical reactions

of the primary and secondary alcohols. Some of the intermediate oxidation products are shown in the following diagram



As mentioned in the chapter on Oxygen, oxidation of fats in the body is accomplished at comparatively low temperatures because of the presence of certain catalytic agents. At the proper kindling temperature fats and oils burn. In fact, fats are frequently used commercially as a source of heat and light. Because of the greater chemical activity of unsaturated compounds, unsaturated fats at ordinary temperatures, even in the absence of a catalyzer, on exposure to an slowly combine with oxygen. This process, called auto oxidation, is involved in rancidity of fats, drying of oil paints or varnishes and in the fat chaines in body cells.

#### SELF-TESTING QUESTIONS

- 12 In what five important ways are fats similar in their physical properties?
   13 What is a simple physical test for a fat?
- 13 What is a simple physical test for a fat?
   14 Name five solvents for fats What fats show a very slight solubility in water?
- 15 How do colloids make permanent emulsions?
- 16 Why is emulsification of great physiological importance?
- 17 What are the products of hydrolysis of fats?
- 18 What causes hydrolysis of fats in the body?
- 19 What is saponification?
- 20 Name two soluble soaps
  - 20 Name two soluble soups 21 What is a soap?
- 22 How may soap and glycerin be separated?
- 23 What chemical reaction takes place when soap is dissolved in hard water?

- 24 How are the following soaps made green soap, scouring soap, germicidal soap, floating soap, washing powder, yellow laundry soap?
- 25 How do you account for the germicidal properties of ordinary lather?
- 26 To what two factors are the cleansing properties of soap due?
- 27 How do you account for some fats being colored and having a rancid odor?
- 28 What is a chemical test for a fat?
- 29 How does burnt fatty food affect digestion?
- 30 How do you account for exidation of fat in the body at such a low temperature?

#### IV. PHYSIOLOGICAL IMPORTANCE OF FATS

# Function of Fats in the Body:

From a physiological standpoint the fats are of great importance in the following ways

As a Fuel Fats are heat producers, and for this reason they have a greater part in the diet during the winter than they do during the summer. The Eskimos in the far north consume large amounts of fats because they need the heat produced. Fats are very poor in oxygen, but rich in carbon and hydrogen. Con sequently fats possess a large amount of latent chemical energy, and take up much oxygen to release correspondingly large quantities of heat. Since one of the important functions of foods is to keep the body at a temperature which is ordinarily above that of the air, fats take first rank among all foods in this respect, and therefore are extremely helpful in preserving animal life.

It is interesting to note again that 1 Gm of fat produces as many Calories (9 3) of heat as 2 Gm of a carbohydrate or protein in oxidation. There is available little information concerning the human requirement of fat. An average liberal duet for a man contains about 90 Gm of fat every day

As a Reserve Fuel Supply The fat content of the body cells varies and it makes up as much as 90 per cent of some adipose tissues, where it serves as a concentrated reserve supply of chemical energy that is available when needed by the body Ordinarily glycogen acts as a reserve supply of energy, but when it is used up, as in starvation, the body begins to burn its own fat as a fuel Too much fat storage, however, interferes with the body's functioning

AS AN INSULATOR AGAINST LOSS OF HEAT Because fat conducts heat very poorly, adipose tissue becomes a very good insulator for

the animal, and thus prevents an undue loss of heat through conduction from the surface of the body. The bodies of animals living in the far north are saturated with fat which provides them with a reserve supply of fuel and a warm coating that conserves body heat. Corpulent people retain their body heat and withstand cold weather much better than thin people.

As a Protecting Agent Since the fat of the body is deposited around the abdominal organs and fills out the body structure, it serves as a support and a 'shock absorber' against injury That fat does act as a supporting structure is evidenced by the fact that a sagging of the viscera is more noticeable in thin people than in fleshy people Furthermore the fat protects the gangha of nerve cells (autonomic), which regulate the normal functions of the abdominal viscera and in this way partially accounts for the insus ceptibility of fleshy people to irritation and indigestion

As a Cell Constituent In addition to fats there is present

As a Cell Constituent In addition to fats there is present in animals a certain proportion of fat like substances classified as complex lipids

## Behavior of Fats in the Body

The ingested fat continues essentially unaltered until it reaches the intestines where the greater part of it is emulsified by the bile and then acted upon by pancreatic lipase (steapsin) which hydro lyzes the fat into a fatty and and glycerol

The glycerol is absorbed directly but the insoluble fatty acids cannot be absorbed as such. They combine with the bile salts to form complex substances which are absorbed. In the final stages of this process the fatty acids are released from the bile salts and enter into reaction with glycerol to produce body fats.

$$C_3H_5(OH)_3 + 3 C_{17}H_{35} COOH \rightarrow C_3H_5(OOCC_{17}H_{35})_3 + 3 H_2O_{Feb}$$

These fats pass by the way of the lymph into the blood. In the absence of bile very little absorption of fat takes place, as evidenced by the increase of fat in the feces when for any reason the bile does not pass into the intestines. At such a time the coloring matter of the bile distributes itself throughout the body, coloring the skin yellow and giving rise to the disorder known as jaundice

Nourishment for such patients should consist largely of carbohydrates and proteins, and the amount of fat should be restricted

## **Assimilation of Fats:**

After absorption of the chyle by the intestinal mucosa the fatty acids and the glycerol recombine to form body fats which pour from the lymph vessels into the blood, and in the form of emulsions are carried to the cells where they are existed. All fats in excess of the amount required by the body for immediate energy are deposited as adipose tissue, which serves as a storehouse of available energy. The amount thus stored constitutes the major portion ingested. Body fat is permeated with a network of blood vessels which make it immediately available for use. An excessive amount of fat, of course, requires a greater number of blood vessels, and causes a strain upon the heart in forcing the blood through these veins.

A person who eats very much sugar, such as candy, is apt to become fat, for sugar (carbohydrate) in excess of that needed at the time is changed to body fat In order that the fat may be oxidized in the body it is necessary to have blood sugar present Blood sugar is normally present in sufficient quantities, but is not available when the pancreas fails to secrete sufficient insulin, which is necessary for both the storage and oxidation of glucose Without insulin there is an inability to "burn" glucose, giving rise to a high sugar content which soon reaches the threshold point, then sugar begins to filter through the kidneys into the urine This condition is called diabetes, it varies with the individual. Diets based on carbohydrate tolerance are used extensively in this disease. The available carbohydrate comes from 100 per cent of the carbo hydrate, 58 per cent of the protein, and 10 per cent of the fat eaten. and is so figured in making a diabetic diet. It should be understood that a diabetic may eat any kind of food provided his sugar tolerance is considered. Every diabetic does not need insulin, since the need for insulin depends on the sugar tolerance

In diabetes, wherein there is a faulty metabolism of sugar, the fat in the blood is often incompletely oxidized and certain fatty acids are formed which produce the acid condition known as ketosis Acidosis results then, when the alkaline reserve of the blood and body is used up at a faster rate than it can be formed in taking care of the acids produced Oxidation of these acids produces acetone, which is frequently found in the urine of diabetic patients, and

sometimes as a sweet odor on their breath. Acetone and the fatty ands, butyric acid, beta hydroxybutyric, and acetoacetic acids, are often referred to as "acetone bodies." Since the ingested sugars are not oxidized, the diabetic is not supplied with sufficient energy, but this condition may be remedied by the suboutaneous injection of insulin. \* Ketosis is often produced in normal individuals by feeding a diet high in fat and low in carbohydrate and protein. In epilepsy, many patients are improved by an acid condition and such a diet rich in fat has been employed extensively in the treatment of this disease.

Fats will be discussed further in the chapter on Metabolism

#### SELF-TESTING QUESTIONS

- 31 Name five important physiological functions of fats in the body
- 32 Why do fats yield correspondingly larger quantities of energy than carbohydrates?
- 33 Explain the chief chemical changes taking place in the passage of in gested fat to body fat
- 34 What emulsifies ingested fats?
- 35 What causes jaundice?
- 36 What conditions are necessary for oxidation of fat?
- 37 What are the functions of insulin?
- 38 What is acidosis and how is it caused?
- 39 How is a diabetic diet figured?

# V. OTHER LIPIDS

# Some Complex and Derived Lipids.

Waxes, like the animal and vegetable fats and oils which have just been considered are classed as simple lipids. In chemical structure the waxes are esters which are derived from high molecular weight fatty acids and high molecular weight monohydric alcohols. These compounds come from both animal and vegetable sources and representative ones are beeswax, lanolin spermaceti, and carnauba wax. Beeswax is to a large degree myricyl palmitate and ester, formula Cl<sub>15</sub>H<sub>31</sub>COOCa<sub>3</sub>H<sub>53</sub>

The compound lipids include phospholipids (phosphatides) and glycolipids. Substances of this nature, when hydrolyzed give some product or products along with alcohols and faţty aeids. Thus the glycolipids upon hydrolysis give a carbohydrate usually galactose, as one of the decomposition products. Glycolipid structures exist.

<sup>\*</sup>Since insulm is a protein and is capable of digestion it must be injected hypodermically into the blood stream

in brain tissue and for this reason have acquired the name cerebrosides

The lecithms are important phospholipids Upon complete hydrolysis these complex esters yield glycerol, fatty acids, phosphoric acid, and a nitrogen base called choline. The latter substance has physiological significance since it prevents the accumulation of fat in the liver, and has the ability to lower blood pressure. Choline is also classed as a vitamin. The structure of a typical lecithin follows.

The leathin pictured here if subjected to a complete hydrolytic breakdown would yield glycerol, stearic acid, oleic acid, phosphoric acid, and choline,  $HO-CH_2CH_2-N(CH_3)_3$  In the body the



lecthins play a part in the transportation of fat and in fat metabo lism, they may also serve as a source of phosphoric acid. In food industries the lecithins are widely used as emulsifying agents

Closely related to the lecthurs are the cephalins. In place of the choline, which is a part of the structure of a lecthur, the cephalins have other introgen bases, frequently ethanolamine, HO—CH<sub>2</sub>CH<sub>2</sub>—NH<sub>2</sub>

Associated with body fat as primary cell constituents are esters derived from fatty acids and complex cyclic alcohols called sterols. Such structures are classified as derived lipids, they have wide occurrence in both the plant and animal kingdoms. Two sterols of considerable importance are cholesterol and ergosterol. Cholesterol is present in the blood in a concentration which ranges from 140 to 200 mg per 100 ml of blood serum. Like the phosphatide,

lecitim, it is apparent that cholesterol also plays a part in regulating fat metabolism. With advancing age, cholesterol can be a contributing factor, if not the cause of artenosclerosis. Certain hormones, and also vitamin D, are structurally closely related to cholesterol.

#### SELF-TESTING QUESTIONS

- 40 What are phosphatides?
- 41 How do phosphatides resemble ordinary fat in physical and chemical properties?
- 42 In what ways are phosphatides important?
- 43 What interest is attached to cholesterol and ergosterol?

## SUGGESTED ACTIVITIES

- I THOUGHT PROVOKING QUESTIONS
  - 1 Why is a fat referred to as a triglycende?
  - 2 How are fats and soaps related to fatty acids?
  - 3 What is meant when it is stated that body fat is always in a liquid condition at body temperature?
  - 4 Why would hydrogenation be of great economic and commercial importance during war times?
  - 5 What chemical reaction would take place if salad dishes containing vinegar or acid foods were put in soapsuds?
  - 6 Why is there a greater variation in the specific gravity of liquid fats than in solid fats?
  - 7 Starting with fat, write the equations to show how nitroglycenne may be made
    8 Why should goods washed in chesp Isundry soons be thoroughly
  - rinsed?

    9 Upon standing exposed to the air, butter becomes rancid What
  - chemical reaction has taken place?

    10 What is the difference in composition between natural fats and
  - phosphatides? Between natural fats and sterols?

    11 Why is it that onions cooked in fat have a different flavor than
  - when cooked in water?

    12 Which is more desirable for pastry making a saturated or partially
  - unsaturated fat? Why?

    13 What are the precautions and reasons you would give in pre
  - serving butter?

    14 In what way would a knowledge of the pH value of a fat be of some value?
  - 15 Linseed oil contains the glyceryl ester of linolenic acid the formula for which is C<sub>17</sub>H<sub>19</sub>COOH
    - (a) What is the general series formula which includes this scid?
      (b) How many double bonds are present? (c) Why does linseed
    - oil dry more quickly than many other unsaturated fats?

soap

brotl

ketosis

phosphatides

II VOCABULARY TESTING OF NEW TERMS

glycolipids choline
phospholipids cephalins

lecthins fat sterols saponification

terols saponificatio

III TOPICS FOR ORAL AND WRITTEN REPORTS
1 The History of Soap Making

2 Varieties of Soap 3 Theories Concerning the Cleansing Action of Soap

4 Germicidal Value of Pure Soap

5 Edible Fats and Oils 6 Relationship between Fat in the Diet and Cholesterol

#### LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on page 725

#### CHAPTER XVII

#### PROTEINS

#### CHAPTER OUTLINE

- I OCCUBRENCE, FUNCTIONS, FORMA IV PROPERTIES OF PROTEINS TION AND COMPOSITION
  - (a) Occurrence and functions of proteins
  - (b) Formation of proteins (c) Composition of proteins
- II. AMINES
  - (a) Physical properties
    - (b) Chemical properties
    - (c) Quaternary ammonium compounds
- III AMINO ACIDS. THE STRUCTURAL
  - UNITS OF PROTEINS
  - (a) Chemical properties 1 Amphoteric action
    - 2 Reaction with oxygen

- (a) Physical properties
  - 1 Foam 2 Solubility 3 Colloids
  - (b) Chemical properties
    - 1 Heat 2 Precipitation
    - 3 Hydrolysis
    - 4 Color tests 5 Protein swelling and
    - coagulation 6 Nitrogenous fibers
- V CLASSIFICATION OF PROTEINS (a) Simple proteins
  - (b) Conjugated proteins
  - (c) Derived proteins
- VI Assimilation of Proteins
- VII RECENT PROTEIN RESEARCH

# I. OCCURRENCE, FUNCTIONS, FORMATION, AND COMPOSITION

# Occurrence and Functions of Proteins:

Proteins exist in all living matter. They form the most important and most characteristic constituents of all living cells, and are present in all fluids of the body, except urine and bile Carbohydrates and lipids, the chief reserve sources of energy for body activity, are also important constituents of the protoplasm of the body cells, but are secondary to the proteins, which are the chief components of the active tissues Muscle tissues, for instance, are made up almost entirely of proteins and contain only small amounts of fats and carbohydrates. The word protein is derived from the Greek word meaning "to take first place" The proteins make up an extremely important group of organic compounds

Since protein substances are essential constituents of all living cells, in that they provide building and repair materials, it is very evident that both animal and vegetable life are impossible without

them Such organisms, however, may exist without food proteins for a varying time but this period is one of existence rather than one of normal life. A lack of protein lowers the body's resistance to disease because without it, the normal amount of disease fighting antibodies is not produced in the blood.



Fig. 1—Animal and Vegetable Proteins. How do an mails and vegetables compare as sources of dietary protein? Courtesy. National Dairy Council

Proteins exist in both plants and animals, however, plants as a group contain very little protein exceptions being the legumes, nuts, and seeds Man derives a part of his proteins from such vecetables as beans, peas, nuts, and the seeds of grains (cereals),

but the larger part comes from such animal sources as meat, eggs, and milk products Animal sources yield very high protein values Although the same kind of carbohydrates and fats are found in both plants and animals, the proteins are not always of the same composition, and we must use a varied duet to get the different kinds of proteins necessary for the muscles, skin, hair, nails, blood, and tissues Gelatin, though cheap, is a poor source of protein because it lacks two important amino acids (tyrosine and tryptophane), and as a sole source of supply would be quite inadequate. Skim milk powder however, is an excellent as well as a cheap source of protein

The table below lists some common foods that are valuable sources of proteins.\* In particular, notice the percentage of protein in peanuts, cheese, and beans

## Formation of Proteins:

The cells of only a few of the plants have the power of taking free nitrogen from the air. The so called leguminous plants, which include clover and altalfa, build their own proteins (a) from the inorganic substances, such as sulfates, phosphates, nitrates, ammonium compounds and water absorbed by the roots; (b) from the carbon dioxide taken from the air by the leaves; and (c) from the nitrogen of the air that is transformed by the nitrifying bacteria of the roots into inorganic nitrogen compounds.

_	~		**	-		_
	Chemistry of	roog and	Nutrition,	Sperman,	Macmillan	Co

Vegetable	Protein Percentage (Approximate)	Anımal	Protein Percentage (Approximate)
Beans (dried) .	22 5	Cheese	25 0
Corn meal .	92	Gelatin	179
Nuts		Eggs	130
Brazil	170	Meat	160
Peanuts .	25 8	Milk	3 3
Walnuts (California)	18 4	l	1
Oatmeal	161	Note Mill	is an economical
Peas (dried)	246	and readily available source of protein, and in addition contains other growth favoring substances	
Wheat flour	114		

Animals also form the protein constituents of their own tissues, but cannot build proteins from simple inorganic substances, such as from the nitrogen of the air, or the nitrates and nitrites. Animals must depend for their nitrogen upon the proteins of the food they eat, and because the food of animals is obtained directly from plants, or from animals that he upon plants, the plant is the real "protein producer" of nature

"Since animals must have proteins for the construction and repair of their own tissues, and since, broadly speaking, they cannot make their own proteins except from the cleavage or decom position products of other proteins, it follows that proteins are necessary ingredients of the foods of all animals. It must not be overlooked that in addition to their function as a tissue builder, the proteins are upon oxidation a source of energy, equivalent, in amount, to that produced by an equal weight of a carbobydrate."

## Composition of Proteins:

The proteins differ in composition from the carbohydrates and fats chiefly in that they contain the element nitrogen. In addition to carbon, hydrogen, oxygen, and nitrogen proteins generally contain sulfur, less frequently phosphorus and a few other elements Since the end products of oxidation of food proteins are acidic and decidedly so if the proteins contain sulfur or phosphorus, it should be remembered that in case of acidosis the more acid proteins should be eliminated from the diet. It is the presence of nitrogen which causes proteins to be so important, and makes them an indispensable part of the diet of every plant and animal

The elements that make up proteins vary somewhat in the composition of the protein molecule. The following table shows the variations in which these elements occur.

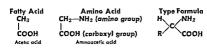
Elements	Extremes of Percentage	
Carbon	50 0 to 55 0	
Hydrogen	60 to 73	
Oxygen	19 0 to 24 0	
Nitrogen	15 0 to 19 0	
Sulfor	0 3 to 2 5 (when present)	

With a few exceptions the molecular weights and complete formulas of proteins are still uncertain quantities. The simplest

<sup>\*</sup> Chemistry of Food and Nutrition Sheeman Macmillan Co.

formula that may be calculated from analysis shows that the molecules of proteins are large and very complex.

Recent experiment has shown that what were formerly thought to be protein molecules with molecular weights around 15,000 are, in reality, only fractions of their estimated molecular weights, and that molecular weights actually range between 43,800 (egg albumin), and 6,630,000 (hemocyanin). Notwithstanding their complexity, an examination of various protein molecules shows that they are composed of fatty acids into the molecule of which has been introduced the amino group (NH<sub>2</sub>), to form a class of substances called amino grate.



#### SELF-TESTING QUESTIONS

- What is the chief function of the proteins?
- 2 What are the vegetable sources of proteins?
- 3 Why must a varied assortment of proteins be included in our diet?
- 4 Why is milk considered as a good source of protein?
- 5 What are the protein producers of nature?
- $6\,$  How do the proteins differ in composition from the carbohydrates and fats?
- 7 Chemically, how are the proteins formed?
- 8 Define a protein from its chemical formation
- 9 In what function are carbohydrates and proteins analogous?

# 11. AMINES

Before proceeding with the study of the proteins it seems advisable to learn something about the nature of the amino group, —NH<sub>2</sub>, which characterizes the amino compounds, and which also is a characteristic group in all proteins.

The simplest way of studying the aliphatic amines is (1) to consider them as substituted "ammontas" wherein one or more alkyl radicals have been substituted for hydrogen in the ammonia molecule, the classification depending upon the number of H atoms replaced.

and (2) to consider their properties as being very similar to those of ammonia

# Physical Properties

From a physical standpoint, the simplest amines resemble am monia by being gases that have a somewhat similar odor and are soluble in water. As the complexity of the molecules increases, the amines become hiquids or soluds with a corresponding decrease in their solubility and in their flammability.

## **Chemical Properties:**

1 Amines React With Water to Form Ionizable Bases Chemically, the amines closely resemble ammonia, except for their combustibility Both ammonia and amines form weak bases in water Strictly speaking, ammonia does not become a base until it has united with water to form ammonium hydroxide

In the same way an amine does not become a base until it has united with water

2 AMINES REACT WITH ACIDS TO FORM IONIZABLE SALTS An amino compound acts as a base, just as armonia does in that the amino compound ionizes and reacts with acids to form salts. A comparison between the action of ammonia with an acid and an amine with an acid to form salts, in which the valence of nitrogen is five, is shown in the following equations.

$$NH_3 + HCI \rightarrow NH_4CI \rightarrow NH_4^+ + CI^ Ammonia Acid Solt$$
 $CH_3NH_2 + HCI \rightarrow CH_3NH_3CI \rightarrow CH_3NH_3^+ + CI^ Acid Solt$ 
 $Acid Solt$ 

3 AMINE SAITS ARE DECOMPOSED BY STRONG BASES Furthermore, amines resemble ammonia in that the amine is liberated from its salts when heated with stronger bases

$$NH_4CI + NaOH \rightarrow NH_3 + HOH + NaCI$$
 $CH_3NH_3CI + NaOH \rightarrow CH_3 \cdot NH_2 + HOH + NaCI$ 
Methylammonium
Chlonde

From this discussion it should be particularly remembered that the  $NH_2$  group gives basic properties to a compound

The aromatic amines, of which the simplest one is aniline, C<sub>6</sub>H<sub>5</sub>NH<sub>2</sub>, closely resemble the aliphatic amines in classification and properties. A number of compounds which have value in medicine are derived from aniline and other aromatic amines

SOME DERIVATIVES OF AROMATIC AMINES USED IN MEDICINE

Amine	Uses		
Acetanilide	Analgesic (relieves pain when given by mouth) Antipyretic (reduces fever temperatures)		
Arsphenamine (salvarsan)	Specific for treatment of syphilis in all stages particularly in primary stage		
Phenacetin	Antipyretic Commercial headache and neuralgia		
Sulfa Drugs e g , Sulfamlamide Sulfadiazine Sulfathiazole	Primarily in infections due to hemolytic streptococc but also effective in pneumonia and other infection Active against nearly all true bacteria		

Complex amines are found to a considerable extent in nature under the name of alkaloids, compounds which have already been discussed (p 192) Amines are sometimes formed in the body as the result of the action of putrefying bacteria upon the proteins. Thus gives rise to a class of poisonous substances called "ptomaines"

Note An amude is an organic acid in which the OH of the COOH group has been replaced by an NH g group or it may be considered as NHs with one H replaced by an acyl group, R-C=0

## Quaternary Ammonium Compounds.

In recent years a number of synthetic quaternary ammonium compounds (so called because the nitrogen in the molecule is joined to four carbon atoms) have been finding extensive use. The cationic "quats" are very effective germicidal and bacteriostatic agents, but in this property they are inactivated by the presence of anionic detergents, soap, and protein containing substances making them meffective in the presence of blood or pus. Many hospitals use "quats" in various concentrations for a variety of disinfectant and antiseptic purposes, both on patients' skin and mucous membranes. and on many types of equipment The quaternary ammonium salts are also effective cationic detergents

### III. AMINO ACIDS: THE STRUCTURAL UNITS OF PROTEINS

With some understanding of the nature of the amino group we are now ready to study the properties of the amino acids, compounds which are called the "building stones of the proteins" Some twenty three different amino acids connected with body chemistry are definitely known, of which number a certain few are absolutely necessary in our daily diet if life is to continue (n. 611) In all, over thirty different amino acids have been obtained as derivatives of the proteins Since all amino acids are synthesized by the plant cell through a photosynthetic process it is understandable how dependent we are upon plant life for our vital proteins

Before proceeding with the study of amino acids it is well to keep in mind that amino acids are organic acids with an amino group (NH<sub>2</sub>) substituted for a hydrogen atom in the alpha\* (α) position, e on the carbon atom next to the carboxyl group

The following list shows a aminoacetic acid the simplest of all amino acids, a aminopropionic acid, the next simpler acid, from which all other amino acids are structurally derived and the several different types of amino acids

#### AMINO ACIDS

I One amino group for each carboxyl group

СН₂—СООН	СН3-СН-СООН	(CH <sub>3</sub> ) <sub>2</sub> CH—CH—COOH
NH <sub>2</sub>	 NH₂	j NH₂
Glycine (gminoacetic acid)	Alanine (a: aminoprop onic acid)	Val ne

<sup>\*</sup> The first carbon next to the acid (COOH) group is called the alpha (a) carbon atom the second carbon atom is the beta (f) the third is the gamma (7), and so on.

Hydroxyproline

lodogorgoric acid

II Two amino groups for each carboxyl group

III Two carboxyl groups for each amino group

## Chemical Properties of Amino Acids

1 AMPHOTERIC ACTION It may be noticed in the following amino acid molecule that there is an acid (COOH) and a basic (NH<sub>2</sub>) group

These two groups make it possible for the compound to act as a base or an acid Such compounds are said to be amphoteric

The following reactions of aminoacetic acid, commonly called glycine, with an acid and with a base illustrate the amphoteric properties of an amino acid.

This dualistic nature of the amino acids accounts for their ability to combine with each other, and in that way build up the complex protein molecule. The linkage of amino acid radicals through the acid carboxyl group (COOH) of one to the basic amino group (NH<sub>2</sub>) of another is illustrated thus:

In the dipeptide, the linkage — C-N- is called the peptide or the biuret linkage.

H

Continued combination between more amino acids by condensation eventually builds polypeptides, peptones, proteoses, and finally proteins. From the above it is quite evident that proteins are combinations of amino acids. The following notation expresses in a general way the nature of the polypeptide chain:

2 REACTION WITH OXYGEN Of particular interest and great importance to the nurse is the understanding of what reaction takes place in the human body when amino acids, in excess of those needed for tissue building, undergo oxidation to produce heat and energy In this oxidation change the amino group is removed to form ammonia and a ketone acid. Using alpha amino propionic acid commonly called alanine as an example the follow ing equation shows what probably takes place in the stepwise ovidation

$$\begin{array}{c|cccc} \text{CH}_3 & \text{CH}_3 & \text{CH}_3 \\ \hline (\text{CHNH}_2 \xrightarrow{\circ} \text{NH}_3 + \text{CO} \xrightarrow{\circ} \text{CO}_2 + \\ \hline (\text{COOH} & \text{COOH} & \text{COOH} \\ \text{a Am nopropion c odd} & \text{Pyrwic odd} & \text{Acelic odd} \\ \text{(letonic odd)} & \text{(letonic odd)} \end{array}$$

Further discussion of the place of aming acids in the tissues will be presented in the chapter on Metabolism (p. 495)

#### SELF-TESTING QUESTIONS

- 10 Explain the statement amines are substituted ammonias
- 11 State three chemical properties of amines that are similar to the proper ties of ammonia
- 12 Name two important aromatic amines and their uses 13 Name a class of naturally occurring drugs which are amines
- 14 To what class of compounds do ptomaines belong? 15 Why is a protein amphotenc?
- 16 What is the peptide or biuret linkage?
- 17 How are proteins formed?
- 18 Define a protein

## IV. PROPERTIES OF PROTEINS

The properties of the proteins are not very clearly defined, even though they do have many common characteristics. What differences do arise in the nature of the many different and complex proteins are for the most part due to the number, the kind, and the arrangement of the various amino acids within the protein molecule. Thus albumin, pepsin—an enzyme—and insulm—a hor mone—are proteins of varying natures. However, with the under standing that proteins are complex molecules of large molecular weight, are combinations of amino acids, and can act as acids or bases, the study of their behavior is less difficult.

# Physical Properties:

The physical properties of the proteins are due largely to their behavior as colloidal substances Their most characteristic physical properties follow

FOAM The proteins are mostly colorless and amorphous compounds, only a few being colored (hemoglobin) and crystalline For the most part, they are typical colloidal substances which foam readily when in solution Milk or blood, for example, foams when agitated as a result of the colloidal material present

SOLUBILITY There is quite a variation in the solubility of the proteins. Some, like the albumins, are soluble in plain water and in salt solutions, others, like the globulins, are soluble only in salt water, while still others are soluble only in an acid or alkali medium. All are insoluble in the common solvents for fats, such as ether

COLLODS Most of the soluble proteins on account of their high molecular weight form colloidal dispersions which do not diffuse through an animal membrane, a very important factor in regulating cell activity. If it were not for this nondiffusable property, all soluble proteins would be excreted through the kidneys and not be retained in the blood stream. It is only when the kidneys are diseased that the cells are permeable and albumin is found in the jume.

Elsewhere (p 111) it has been stated that proteins are positive in a medium more acid than the isoelectric point and negative in a medium which is less acid than the isoelectric point. Proteins are colloids and adsorb water (p 113), and acids or bases increase the

adsorption of water and make protein foods more tender Most proteins have a negative charge in a neutral solution

# Chemical Properties

1 PROTEINS ARE DECOMPOSED BY HEAT The chemical be havior of the proteins is that of the amino acids of which they are composed. When heated, they gradually decompose, gruing off a strong odor like burnt wool or hair, and when in a colloidal dispersion they may be precipitated by a variety of agents, all depending upon the kind of proteins present

2 Proteins Are Precent present
2 Proteins Are Precent Payer By Heat Under the influence of heat the molecules of a dispersed protein tend to run together to form an insoluble protein. This form of precipitation or coagulation is called denaturation. It differs from ordinary precipitation in that the change is permanent and the albumin now a denatured protein, cannot be restored to its former state though it can be dissolved by acids, bases, urea and other reagents. The change and appearance of the white of an egg after cooking are a good example of coagulation, a condition which increases the digestibility of egg albumin, hemoglobin, and many other proteins. Since living cells contain proteins, heat coagulates and kills them. The spores of certain bacteria, however, are very resistant to heat. This is because they contain very hitle water and are coagulated only at extreme degrees of heat. This resistance of spores and dried proteins to coagulation accounts for the supercipity of most heat (steam) over dry heat in sterilization. From the preceding state ments it is evident that heat may sometimes be used as a simple test for a goluble protein, such as albumin in asthological urune.

By Salts of Heavy Metals (HgCl<sub>2</sub>, AgNO<sub>3</sub>, CuSO<sub>4</sub>, Ph(C<sub>2</sub>H<sub>2</sub>O<sub>2</sub>)<sub>2</sub>). Since proteins can act in part as acids because of the -COOH group it is evident that proteins may react with salts to form other acids and salts.  $e \ g$ ,

R—CH(NH<sub>2</sub>)COOH + NaCl → R—CH(NH<sub>2</sub>)COONa + HCl

The sodium salts of dispersed proteins can be expected to be soluble. Some metallic salts though, may form insoluble proteinates. For example, salt solutions of heavy metals have long been used for their antiseptic and germical properties since they coagulate proteins. Bichloride of mercury is one of the very im

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portant disinfectants, but even so it may not be used for this purpose when the parts to be sterilized contain a great deal of protein (vomit, stools, etc.), since in the coagulation the mercuric chloride combines and forms with the proteins an enveloping capsule that prevents further penetration of the antiseptic Thus in the case of poisoning from bichloride of mercury, it is easily under stood why the white of egg or milk is introduced into the stomach of the patient. Even though the absorption and distribution of the posion are retarded, there is a tendency for the coagulated protein to redissolve in the course of digestion and to be absorbed to attack the tissues, especially the kidneys. For that reason, immediate action should be taken to remove the contents of the stomach.

Silver compounds are widely used in medicine to produce caustic, astringent, and antiseptic effects, actions which are largely due to free silver ions. Such a compound is silver intrate, which coagulates cell constituents and secretions by entering into chemical combination with the proteins present. This action has a tendency to stop any further caustic effect, and the antiseptic action that follows is due to the slow freeing of silver ions from the silver protein compounds that had been formed.

The value of lead acetate as a skin antiseptic, and copper sulfate as a spray (Bordeaux mixture), is also based upon this coagulating effect

By Alcohol Alcohol is a very common antiseptic, in that it coagulates bacteria (proteins), but if the alcohol is 95 per cent there is very little germicidal action, because like the bichloride of mercury, the formation of a protective envelope keeps the alcohol form passing through the protein, and at the same time withdraws water from the bacteria. The addition of water revives them. In hospitals, a 70 per cent alcohol solution is generally used on the wards for antiseptic purposes and as an alcoholor rub because at this concentration bacteria are killed rapidly. The water probably keeps the alcohol in contact with the bacteria a longer time and prevents too rapid evaporation.

By Acids Since the proteins also have a basic group, "NH2, in their molecules they may react with acids to form salts, some of which are insoluble

The organic acids, picric, tannic, and phosphotungstic, are principally used for the purpose of precipitating proteins, and are often called alkaloidal reagents. Advantage is taken of this effect in using picric acid as a coagulating test for albumin in the urine (Esbach's

test) In the leather industry, tannic acid extracted from the bark of certain trees (oak hemlock) renders protein hard and free from bacterial action Tannic acid (and sometimes picric acid) is also used in the treatment of burns to combat shock, toxemia and sepsis (poisoning of system). As an astringent it contracts the tissues to lessen the secretion of the precious body fluids, to prevent the absorption of toxic protein disintegration products resulting from the injured tissues, and to relieve pain by protecting exposed nerve endings with a restraining eschar over the burned area Frequently this treatment is followed with a dilute solution of silver intrate. Spraying sulfadiazine directly on burns is still hailed as a very effective treatment.

The bitterness or puckering sensation of strong tea and of underripe fruits is due to the effects of tannic acid on the proteins of the mircous membranes

The inorganic acids also precipitate proteins. This action is put to good advantage in using intro acid to make a test for albumin in the urine, the acid precipitating a ring of protein at the junction of the urine and the acid (Heller's ring test). With an excess of the acids, the precipitated proteins act as a base and redissolve Also, in the presence of an excess of strong alkali the precipitated proteins act as an acid and dissolve. This explains the action of both acids and bases upon woolens (p. 159). It is also on account of this dualistic nature of the proteins that we are able to explain how the protein assists in regulating the acid base balance of the blood (p. 186).

Precipitation Explained From the foregoing it is evident that the proteins may be precipitated unaltered or as insoluble salts Also, the addition of some salts like sodium chloride, ammonium sulfate, and magnesium sulfate will remove water from the col loidal protein particles and cause them to "salt out" or precipitate It is in a similar way that alcohol precipitates proteins. On the other hand, the insoluble state may be due to a chemical reaction

Proteins are amphoteric substances and therefore they may behave as either acids or bases depending upon the pR of the environment. In a medium more acid than its isoelectric point a dispersed protein exists primarily as positive ions. Consequently it can react with the anions of certain acids to form insoluble salts. The addition of tannic acid to produce an insoluble protein tannate illustrates this.

When a protein is dispersed in a medium which is less acid than

its isoelectric point it forms negative ions ie, amons. In this condition the protein is capable of reacting with heavy metal cations, and other complex cations, to give insoluble proteinates. These are salt-like structures. The addition of mercuric chloride, HgCl- to a protein in a sufficiently alkaline medium leads to the precipitation of a mercuric proteinate.

It is interesting at this point of the discussion to take note of the fact that the alkaloids also precipitate the proteins as proteinates Moreover, it is important enough to mention again that proteins of the blood, because of their amphotenic properties, can act as buffers in regulating the acid base balance by preventing any changes in hydrogen ion concentration when small amounts of acids or bases enter the blood stream

3 Proteins Undergo Hydrolysis Proteins, like the carbohydrates and fats, can undergo hydrolysis which may be brought about by dulute acids, alkalies or by the digestive enzymes When hydrolysis, as in digestion does take place, it occurs in stages, each successive stage forming a simpler molecule by splitting off amino acids Such a hydrolytic reaction is just the reverse reaction of how amino acids are linked together in the protein molecule (p 387) The following equation shows how hydrolysis may take place at the peptide linkage to form amino acids from a dipeptide

$$\label{eq:NH2CH2} \begin{aligned} \text{NH}_2\text{CH}_2 & \xrightarrow{\text{COOH}} + \text{H}_1\text{OH} \rightarrow \text{NH}_2\text{CH}_2 & \text{COOH} + \text{NH}_2\text{CH}_2 & \text{COOH} \\ & \text{Glycylegive ne (d pept de)} \end{aligned}$$

Upon hydrolysis of proteins proteoses are first formed, then upon further disintegration, peptones are produced. The latter substance is still a true protein, but contains a smaller number of amino acids. Upon further division we no longer have proteins, but simpler groups of amino acids called polypeptides. These, in turn, break down into peptides and amino acids, a form in which all proteins must exist before they may be absorbed. The successive steps in hydrolysis during digestion are as follows.

$$\begin{array}{c} \text{Proteons} \xrightarrow{\text{H}_2\text{O}} \text{Proteoses} \xrightarrow{\text{H}_2\text{O}} \text{Peptones} \xrightarrow{\text{H}_2\text{O}} \\ \text{Polypephdes} \xrightarrow{\text{O}} \text{Peptones} \xrightarrow{\text{H}_2\text{O}} \\ \text{Amino Acids} \end{array}$$

The amino acids so formed in the course of digestion are absorbed and then used mostly by the liver to build body proteins

The proteins differ mainly in the number and kind of amino acids produced by hydrolysis, some proteins not even producing the amino acids which are necessary to maintain growth or even to sustain life (p. 611). From this statement it is evident that the biological value of proteins is mostly determined by the amino acids formed on hydrolysis, and that any deficiency in the number or variety limits their value. As previously stated, some twenty-three different amino acids are known in connection with hody functions.

In connection with this it should be remembered that the digestion of all foods, as carbohydrates, fats, and proteins, is a series of hydrolyses which break the complex molecules into simpler ones.

4. PROTEINS GIVE COLOR TESTS: Tests for proteins are not only dependent upon precipitation or coagulation but also upon color reactions with certain reagents. The best known color tests are Millon's and the bitter test. Heating a protein with Millon's reagent (mercury dissolved in nitric acid) produces a brick red color

Test Name	Reagent Composition	Color	Cause of Color
Biuret .	Strong alkalı and a few drops of dilute CuSO.	Violet shade	2 biuret or pep- tide linkages O H      -C-N-
Millon's	Mercury metal dis- solved in cone nitric acid, then diluted	Reddish	Hydroxylphenyl group —CeH4(OH) (tyrosine group)
Xanthoprotesc	HNO <sub>3</sub>	Yellow, deepening to orange when scid is neutralized with alkali	Benzene ring, as Tyrosine Tryptophan Phenylalanine
Hopkins-Cole	Glyoxalic acid CHO—COOH	Violet	Indole group of Tryptophan C C CH

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or precipitate, while with the biuret reagent (a few drops of dilute CuSO<sub>4</sub> in concentrated NaOH) it produces a violet to pink color (dipeptides excepted) A very familiar protein reaction is the yellow color produced by nitric acid on the skin Upon the addition of an alkali the color changes to an orange, giving what is known as the xanthoproteic or "yellow protein" test Since there is a variance in the kind and number of groups in different proteins, there will be various color tests. As a consequence too much reliance should not be placed upon a single test to indicate the nature of a protein. The most important color tests for proteins are shown in the table on page 394.

# Protein Swelling and Coagulation

As has been stated (review, p 111) proteins are neutral at the isoelectric point but become positive in a more acid solution, and negative in a more alkaline solution. When acid to the isoelectric point, the colloidal proteins in the body have a great affinity for water. Thus an accumulation of lactic acid as the result of violent exercise or delayed metabolism produced by anesthetics or toxins can result in swelling. To repress this swelling (edema) certain salts (alkali tartrates, acetates, phosphates), or fruit acids have been recommended

According to some authorities anesthesia is due to a coagulation of some of the proteins of the brain and sensory nerves Habitforming drugs, such as morphine, coagulate nerve proteins and act as they do because they are not eliminated very rapidly, whereas the true anesthetics (ether, mirrous oxide, chloroform) are eliminated from the body in a very short time

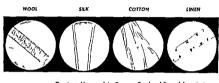
A brief discussion of allergic reactions caused by proteins is presented on page 436

## Nitragenaus Frhers:

Animal fibers such as hair, wool, and silk belong to a class of proteins called keratins, compounds which are characterized by their great insolubility in neutral solvents, but being proteins, they are amphoteine and therefore are capable of reacting as bases or acids. For instance, wool and silk readily dissolve in 10 per cent sodium hydroxide solution, and turn yellow in warm nitric acid (xanthoproteic reaction). Cold, concentrated hydrochloric acid,

however, has little effect on wool, and dissolves silk but very slowly When ignited, animal fibers burn only so long as they are held in the flame, give off an odor like burning hair, and form a small tarry knob at the end of the fibers Wool in particular is very sensitive to heat, the fiber becoming very brittle at 100° C

Under the compound microscope all fibers, whether animal or vegetable in nature, show definite characteristics



Courlety, Microonolytic Division Food and Drug Administration

Cells overlap 
like scales Smooth solid 
round Fattened, twisted, Irregular, jointed 
resembles deflored 
tube 
Fig 2

Fig 3

Two important synthetic introgenous fibers have been produced. These are Lantal, a woolen substitute made from casem, and nylon, as all substitute made basically from coal, air, and water Nylon has proved to be a very successful synthetic, and is widely used for hossery and other wearing apparel, bristles for brushes, surgical sutures. machine bearines, and a host of other thinsy Undoubtedly

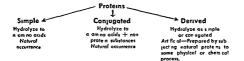
# it has brought about a curtailment of the natural silk industry

- 19 State the physical properties of proteins
- 20 How do the proteins differ in their solubility?
- 21 What is a simple test for a soluble protein?
- 22 What metallic salts form insoluble proteinates?
- 23 What are the functions of a 70 per cent alcoholic solution on the skin?
- 24 What is Heller's ring test?
- 25 What medicinal advantage is taken of the coagulation action of picric and tannic acids on proteins?

- 26 Why are proteins soluble in both acids and alkalies?
- 27 How may proteins be separated from solution unaltered?
- 28 To what principle is this latter separation due?
- 29 What intermediate products are formed upon hydrolysis of proteins?
- 30 What are all tests for proteins based upon?
  - 31 State two color tests for proteins
- 32 How do you account for swelling in proteins?
- 33 What effect do anesthetics and alkaloids have upon proteins of the brain and sensory nerves?

#### V. CLASSIFICATION OF PROTEINS

The number of different proteins is almost unlimited. Certain proteins have similar characteristics, and accordingly they may be placed in three principal classes the simple, the conjugated or compound, and the derived proteins.



# Simple Proteins

The simple proteins are the native or true proteins which upon complete hydrolysis yield amino acids only

The principal members of simple proteins are the albumins and the globulins. Both of these occur in blood serum, in the white of eggs, in meat, in the whey of milk, in the gluten and legumin of plants, in the myosin of muscle protein, and the fibrinogen of blood plasma. Their properties are very similar, differing chiefly in their solubility in water and in salt water. The albumins are very abundant in animal fluids (blood, etc.) while the globulins predominate in the tissues. Since both the albumins and globulins form colloidal dispersions in very dilute salt solution it is evident that the boiling of meat in a dilute salt solution, as in the preparation of soups or stews, results in the extraction of these nutritive proteins.

### CLASSIFICATION OF SIMPLE PROTEINS

Subdivision	s	Properties Solubility and Effect of Heat (Basis of Classification)				Examples and	
Suparvision	H₂O	Salt Sol	Dil Acıd or Alkalı	Alcohol	Coag by Heat	Remarks	
Albumins	+	+			+	Ovalbumin (egg white), serum albumin (blood), lactalbumin (milk), vegetable albumins Abundent in animal fluids	
Globuluna		+			+	Serum globulin, muscle globulin (myosin) veg etable globulins Predominate in the tis sucs	
Glutelins			+		+	Glutenin (wheat)	
Prolamines				70 to 80		Gliadin (wheat), zein (corn)	
Albuminoids						Collagen (tendou) Kera tin (hair, hoof horn) Elastin (ligament) Principal part of skel etal structure and pro- tecting tissue	
Histones	+		+		_	Globin (blood) Basic proteins	
Protamines	+					Saimine (saimon sperm) Simplest of natural proteins a polypeptide Basic properties no food value precipitates solu tions of other proteins	

Myosin, a muscle protein, is a globulin, the coagulation of which, after death, produces what is called rigor mortis.

# **Conjugated Proteins:**

Conjugated, or compound, proteins are those which have a protein molecule united to some other molecule of a nonprotein substance. Upon hydrolysis they yield both amino acids and non-protein substances. The following table is a classification based upon the nature of the nonprotein constituent.

# CLASSIFICATION OF CONJUGATED PROTEINS

Subdivision	Compound Proteins (Basis of Classification)	Examples and Remarks
Nucleoproteins	Protein + nucleic acid	Nucleoproteins in thymus, spleen, pancreas, glandular tissue Hydrolyze to purine bases
Glycoproteins	Protein + carbohydrate- group	Mucin (saliva, body secre- tions) Hydrolyze to yield a sugar which reduces Benedict's solution
Phosphoproteins	Protein + phosphate- group	Casein (milk), vitellin (egg yolk)
Hemoglobins	Protein + hematin (iron compound)	Hemoglobin (blood) Hydrolyzes to histone, globin and hematin
Lecithoproteins	Protein + lecithin	Fibrin, egg yolk

Blood contains the soluble simple protein fibrinogen (globulin), which upon exposure to air coagulates and is changed into an insoluble conjugated protein called *fibrin*. The most accepted theory (Howell's) to account for the formation of the blood clot is presented elsewhere (p 448),

### **Derived Proteins:**

The derived proteins, as the name implies, are an artificial group obtained from the simple and conjugated proteins by the action of

acids, alkalies, heat, or enzymes. They are less complex than the simple or conjugated proteins and do not occur in nature. Upon hydrolysis the derived proteins again divide into two groups, the primary and the secondary derivatives; the primary are the result of a very slight hydrolysis, while those of a more extended hydrolysis represent the secondary derived proteins. The classification based upon their hydrolytic changes is shown in the following table.

## CLASSIFICATION OF DERIVED PROTEINS

	Subdivision	Derwed by Hydrolysis (Basis of Classification)	Examples		
Pro	oteins	Insoluble proteins produced by water, enzymes, acids	Casem (curdled milk) Fibrm (coagulated blood)		
Primary	Metaproteins	Insoluble proteins produced by fur ther hydrolytic action of water, enzymes, and acids Soluble in weak acids and alkalies	Acid metaprotein Alkali metaprotein		
Đ,	Coagulated Proteins	Insoluble proteins, the result of heat and of alcohol	Cooked egg albumin		
,	Proteoses	Soluble in H <sub>2</sub> O, precipitated by saturated (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> solution Slightly diffusible			
Secondary	Peptones	Soluble in H <sub>2</sub> O, not precipitated by saturated (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> More diffusible			
Š	Peptides	Soluble in H <sub>2</sub> O, sumplest combina- tions of two or more smino acids Very diffusible	Di-, tri, tetra-, and pentapeptides		

# VI. ASSIMILATION OF PROTEINS

The proteins, according to present view, are transformed partly in the intestinal contents and partly in the intestinal mucosa into amino acids, which either pass to the cells to build tissue, or to the liver where they form urea. Further discussion is presented in the chapter on Metabolism.

## VII. RECENT PROTEIN RESEARCH

The investigation of proteins is a field of very active biochemical research, and in concluding this chapter it is appropriate to give biref attention to some of the newer developments. Three areas of intensive study are to be noted (1) analysis and synthesis of protein molecules, (2) the "gross" nature of proteins, and (3) the significance of the nucleoproteins

(1) As we have learned, natural protein molecules are exceed ingly complex with molecular weights so great that they can truly be called macromolecules. Yet all proteins, regardless of source or complexity, are the result of joining together numerous amino acids via peptide linkages. Some thirty different alpha amino acids have been found in the proteins. There are two general approaches to acquiring insight into the protein molecule, namely analysis and synthesis. It is to be noted that characterizing the structure of a given protein requires knowing not only which amino acids are present and how many residues of each, but also the sequence in which the various amino acid residues appear in the polypeptide chain.

Three protein type substances have at this time been studied to the point where their structures are believed to be known These are insulin, a hormone, ribonuclease, an enzyme, and the tobacco mosaic virus. All of these are relatively simple proteins, and in fact they might better be characterized as enormous polypeptides. For example, ribonuclease contains 124 ammo acid residues. In each case the elucidation of structure came about by analysis, i.e., by hydrolysis of the natural substance into fragments which could be identified. Synthesis has also proved useful. Bio chemists have succeeded recently in synthesizing a polypeptide made up of twenty three ammo acids which shows the biological activity of ACTH (adenocorticotropic hormone). Hence it can be said that the portion of the ACTH structure in which the biological activity resides has been synthesized in the laboratory. In the body, ACTH is secreted by the pituitary gland.

(2) We turn now to a consideration of the over all or gross structures of the proteins. Much of the information of this nature has come to light by the use of the electron microscope and the xray. The problem is more physical than chemical since it becomes a matter of determining how the long polypeptide chains are oriented in the structure of the protein. Proteins appear to have two general shapes, globular or fibrous. In the silk protein fibroin, it is believed that the polypeptide chains have a zigzag form and lie side by side, with cross links to hold them together. The alpha keratin protein of hair is considered to have a helical, spiral like shape. In the globular proteins the chains of polypeptides are possibly twisted like a loose tangle of string, or folded in a pleated fashion.

(3) All living cells contain nucleoproteins By classification these are conjugated proteins. When a nucleoprotein is partially hydrolyzed each molecule gives a protein molecule and a non protein molecule. The nonprotein portions are known as the nucleic acids. These in turn are very high molecular weight substances which are made up of sequences of residues of introgen bases (purnes and pyrimidines), pentose sugar and phosphoric acid. Those having the sugar robose as part of the structure are termed RNA (ribonucleic acid) while those containing the sugar devyribose are termed DNA (deoxyribonucleic acid). As many as 5000 of the nitrogen base pentose sugar phosphate sequences (mono nucleotide units) are present in DNA.

There is now evidence to support the belief that the nucleic acids enable the cells to store and transmit genetic information DNA plays a significant role in chromosomes. Theories concerned with the ability of the nucleic acids to control the synthesis of molecules and to transmit hereditary traits point to the possibility of some exciting discoveries about the nature of life itself.

# SELF-TESTING QUESTIONS

- 34 Upon what basis are the proteins classified?
- 35 Discuss the occurrence and difference in solubility of two simple proteins
- 36 What causes rigor mortis?
- 37 Account for the formation of the blood clot and then classify the proterns involved
- 38 How are the derived proteins obtained?
- 39 What happens to the amino acids after leaving the intestine?
- 40 What is a macromolecule?
- 41 What are the two general physical shapes shown by proteins?
- 42 What is the relationship of nucleoproteins to nucleic acids?

#### SUGGESTED ACTIVITIES

- I THOUGHT PROVOKING QUESTIONS
  - 1 How are the ammes classified?
    2 Why is HgCl<sub>2</sub> an excellent germicide?

- 3 How do you account for the fact that blood serum when diluted with water will become cloudy, but when diluted with physic logical saline solution there will be no cloudiness, rather a clear solution?
- 4 When might not HgCl2 be effective as a disinfectant?
- 5 In making nutritive broth why should the meat be placed in cold galf water?
- 6 In preparing a meat by stewing why cover with hot, clear water?
- 7 In using beaten egg white to make cakes why do they not "fall" after baking? 8 Name several astringents used in nursing procedures and explain
- why they are so used 9 Name five important amino acids that cannot be synthesized by the
- body and state the function of each 10 How is therexin formed in the body and how does it function?
- 11 Why regulate the protein of a diabetic?
- 12 In cleaning milk bottles, dishes with egg on them, and fabrics stained with blood or mucous secretions, why should cold rather than hot water treatment be the first procedure in attempting to remove the clinging proteins?
- 13 How may the amino acids in body cells lymph and blood assist in maintaining a normal vH in these fluids?
- 14 In preparing a meat stock for soups why is salt added before the meat is cooked?
- 15 How successful have chemists been in synthesizing proteins?
- 16 The fact that wet hair can be stretched suggests what kind of physical structure for the protein of hair? II VOCABULARY TESTING OF NEW TERMS

conjugated proteins

derived proteins

amphoteric amines

protein

amino group

peptide linkage simple proteins amino acid III TOPICS FOR ORAL OR WRITTEN REPORTS

- - 1 Chemical Changes during Cooking of Proteins 2 The Relationship of Amino Acids to Proteins
  - 3 The Problem of Complete and Incomplete Proteins in the Diet

## LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on page 729

### REVIEW OF DEFINITIONS

#### CHAPTERS XII THROUGH XVII

The following terms are important in the study of chemistry. A familiarity with them will help in building a scientific vocabulary that will be invaluable.

acidosis (as id o sis) A pathological condition in which acetone and certain acids are present in the body in abnormal amounts

al cohol Hydroxyl substitution product of a hydrocarbon

EXAMPLE CH2OH methyl alcohol

aldehyde (al de hide) The first oxidation product of a primary alcohol A hydrocarbon wherein a hydrogen has been replaced by the —CHO group

aliphatic compounds (al e-fat ik) Open chain compounds

amines (am ins) A group of organic compounds containing the amine (NH<sub>2</sub>) group. They are substituted ammonias

EXAMPLE CH3NH2 methylamine

amino acids Compounds derived from the fatty acids by the exchange of a hydrogen atom of the hydrocarbon radical for an amino group

EXAMPLE CH2(NH2) COOH, aminoacetic acid

amino group (amin-o) The NH2 group which characterizes the amines

amphoteric compounds (am fo-terik) Compounds that may act either as a base or an acid

EXAMPLE Protein

aromat'ıc compounds Ring or cyclic compounds related to benzene CeHs
Many have fragrant odors

EXAMPLE Methyl salicylate (oil of wintergreen)

biological chemistry Study of chemistry of life

EXAMPLE Study of digestion

carbohydrates (kar bo-hi drates) A group of compounds including the sugars, starch, gums, and cellulose They contain hydrogen and oxygen in the ratio of two to one, with but a few exceptions

EXAMPLES C6H12O6, C12H22O11, (C6H10O6),

carbonyl (kar'bon il) A characteristic group in aldehydes and ketones

EXAMPLE = C=0

carboxyl (kar box il) The characteristic group of an organic acid

conjuga'ted proteins Compounds which upon hydrolysis yield amino acids and a nonprotein substance

EXAMPLE Hemoglobin

derived proteins. Compounds obtained from simple or conjugated proteins by the action of acids, alkalies, heat and enzymes

EXAMPLE Proteoses, peptones peptides

disaccharides (di sak ar ids) Carbohydrates which will hydrolyze into two molecules of monosaccharide

EXAMPLE (C6H10O5)2 H2O or C12H22O11

es'ter Compound formed by the displacement of the hydrogen of an acid by a hydrocarbon radical

EXAMPLE C2H5NO2, ethyl nitrite

ether A hydrocarbon oxide

EXAMPLE (C2H5)2O, ethyl ether

fat A glyceryl ester of a fatty acid

EXAMPLE C3H5(C18H35O2)3 glyceryl stearate (stearan)

fermenta'tion The reaction of bacteria, yeasts, or molds on carbohydrates

EXAMPLE Alcoholic fermentation of glucose

fractional distilla'tion Separation of liquids based upon the difference in their boiling points

glycosurus (gl<br/> ko su're-a). A condition wherem an abnormal amount of sugar 19 found on the terms<br/>  $\,$ 

heterocyclic (het-er-o-si'klik) Pertaining to ring compounds which contain other atoms in addition to carbon atoms, as part of the ring

homologous series (ho-mol o gus) Compounds with similar chemical structure and properties, and arranged in order of their molecular complexity

EXAMPLE Methane (CH4), ethane (C2H5), etc

### hydrocar'bon. A compound composed of carbon and hydrogen EXAMPLE CH4, methane

hydrogena tion A process of changing an unsaturated fat to a solid saturated fat by the addition of hydrogen in the presence of a catalyst (Ni)

### EVAMPLE Olam to steam

hydrolysis (hi drol is is) Any chemical decomposition reaction involving water

EXAMPLE (CaHioOs), + X HoO - X CaHioOs

hydroxy acids (hi droka e) Acids containing one or more hydroxyl groups in addition to the carboxyl group

EXAMPLE CHACHOH COOH lactic acid

isomeric (i so mer ik) Pertaining to compounds of the same percentage com position but having different structures and properties

EXAMPLE Sucrose and maltose (C12H22O11)

ketone (ke tone) An oxidation product of a secondary alcohol. EXAMPLE CHa CHa CHa

lin ids or lin oids. A general name for fats and fat like substances mixed other. Ethers in which the alkyl radicals are different

EXAMPLE CHa-O-CaHa methyl ethyl ether monosaccharides (mon-o sak ar ids) Carbohydrates which cannot be solit into

simpler saccharides EXAMPLE CaH10Ox H2O or CaH12Oa

organic chemistry Study of hydrocarbons and their derivatives EXAMPLE CH4 CH3Cl CH3OH

pep tide linkage The -C-N- group sometimes called the biuret linkage phosphatids or phospholipids (fos fa tids fos fo lipids). Substituted fats con taining phosphoric acid and nitrogen

EXAMPLE Lecithin

polymer (pol im-er) A compound formed by the process of polymerization EXAMPLE Paraformaldehyde from formaldehyde

polymerization (pol im-er i-za shun) A reaction between like molecules with out loss of any atoms or groups of atoms

EXAMPLE CaHa to CaHa H CHO to (H CHO)2

polysaccharides (pol 1 sak'a rids) Carbohydrates containing several saccharide groups

EXAMPLE (CeH10Os).

primary alcohol An alcohol characterized by a -CH<sub>2</sub>OH group EXAMPLE R-CH<sub>2</sub>OH

protein (pro te in) Substances composed of H, C, O, N, and sometimes other elements that yield on hydrolysis amino acids or their derivatives

sacchardes (sak a rids) The carbohydrates in the mono , di , and polysacchardes EXAMPLE CaH: 00x

saponifica'tion The process of a fat reacting with an alkali to form a scap

saturated compounds Compounds incapable of addition products

EXAMPLE Any member of the methans series

secondary alcohol An alcohol characterized by a CHOH group

simple ether Ethers in which the alkyl radicals are the same EXAMPLE C<sub>2</sub>H<sub>5</sub>.—O.—C<sub>2</sub>H<sub>5</sub>, ethyl ether

simple protein Compounds which upon hydrolysis yield amino acids or their derivatives

EXAMPLE Albumin

soap Metallic salts of fatty acids

EXAMPLE C17H35COONs, sodium stearate

substitution products Compounds formed by an element or a radical replacing another element or radical in a compound

EXAMPLE From CH4 forms CH3Cl or CH3OH

tertiary alcohol (ter shi a re) An alcohol characterized by a COH group

unsaturated compounds Compounds capable of forming addition products

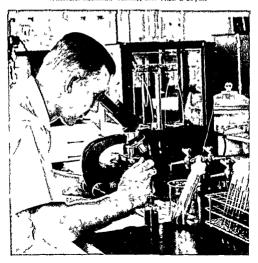
EXAMPLE Any member of the hydrocarbon series ending in ene

# PART III

# BIOCHEMISTRY

A STUDY OF THE CHEMICAL CHANGES TAKING PLACE DURING LIFE PROCESSES

A Research Biochemist. Courtesy, Chas Pfizer & Co , Inc



#### INTRODUCTORY NOTES

#### TO THE INSTRUCTOR

In this division of chemistry, known either as biochemistry or physiological chemistry, we shall take up a discussion of life processes in the light of the organic chemistry just studied. All living organisms perform the three main functions of (a) reproduction, (b) transformation of food into materials switable for growth and repair, and (c) exidation of these substances to furnish heat and energy so essential for the maintenance of life. In general, the subject involves a study of the chemical composition of living matter, the nature of the particular composition of living matter, the nature of the particular composition during growth and decomposition, and the function of each of these substances. In particular, it deals with (1) the digestion of food, (2) the absorption of food products, (3) the blood as a circulating medium which carries nourishment to the cells and simultaneously carries their refuse to the excretory fluid.

This study enables the student to gain a better understanding of the chemical changes of normal living, of pathological living, and of the course of disease as well as its diagnosis and treatment in addition, biochemistry is the fundamental bass of the study of diet in all its ramifications including such applications as occur under the name of dietotherapy

It is almost impossible in the presentation of biochemistry not to duplicate subjects studied in other courses, especially in physiology, diet and nutrition, and some aspects of medical nursing These correlated subjects, however, may be presented from a different viewpoint in the chemistry course, and new chemical facts may be considered herein not mentioned or stressed in other courses. The instructor will do well, however, to insist that all students review such subjects in their other texts, before coming to the chemistry class.

#### OBJECTIVES

# 1. Facts and Principles:

- (a) To understand the function of the alimentary tract and how certain glands aid in this functioning.
- (b) To know the functions of the blood.
- (c) To learn the more important and generally accepted theories concerning the metabolic changes taking place in the tissue cells.
- (d) To study the urine, the chief excretory product of metabolism.
- (e) To understand the necessity of accessory food factors, whose absence leads to profound pathological changes.
- (f) To consider the activities of the endocrine organs which synthesize hormones that play an important role in regulating body processes.
- (g) To gain some understanding of the chemistry involved in physiology and nutrition.
- (h) To establish a relationship between the composition of chemical components of the body and the normal functioning of the tissues.

# 2. Attitudes:

- (a) To develop an appreciation of the physical basis of good health and the ways of preserving it.
- (b) To apply previously acquired knowledge of such allied sciences as zoology, bacteriology, pharmacology, and pathology and to correlate this with the modern understanding of the composition of the cell, the foodstuffs, and their relation to digestion and metabolism.
- (c) To build up a scientific attitude toward life processes.
- (d) To realize how a knowledge of chemistry broadens our interpretation of phenomena in everyday life.
- (e) To realize that biochemistry assists in an understanding of the composition of tissues and foods, and their general course of conduct in metabolism.

#### CHAPTER XVIII

## THE CHEMISTRY OF DIGESTION

#### CHAPTER OUTLINE

- I Foons

  - (a) The purpose of foods (b) Necessity for digestion (c) Digestive fluids
- II ENZYMES AS CATALYSTS (a) Nature of enzymes
  - (b) Nature of enzyme action
  - (c) Specificity
- (d) Classification
- III BEHAVIOR OF ENTINES
  - (a) Properties of enzymes (b) Effect of temperature
  - (c) Effect of hydrogen ion concentration

- (d) Coenzymes
- (e) Zymogen
- (f) Enzyme mactivation, anti enzymes
- IV THE DIGESTIVE FLUTDS
  - (a) Cooking vs digestion
  - (b) Salivary digestion
  - (c) Gastric digestion
  - (d) Intestinal digestion (e) Bile

  - V. BACTERIAL DIGESTION AND AB SORPTION (a) Bacterial action in the colon
    - (b) Absorption
    - (c) Feces

## i. FOODS

## The Purpose of Foods:

Thus far, we have been considering the structure and the prop erties of three large classes of foodstuffs (carbohydrates, fats, proteins). These materials, in a general way, together with the vitamins, water, and mineral matter taken in with them, serve (a) to supply energy, (b) to build tissue, and (c) to prevent disease by regulating body processes. The ultimate object, however, in studying foods is not so much to learn their behavior in test tubes. but to investigate the chemical changes that these complex substances undergo after they enter the body.

## **Necessity for Digestion:**

The purpose of digestion is to prepare the food in such a form that the nutrational constituents may be taken up readily from the alimentary tract by the blood, leaving the undigestible residue to be excreted by the bowel. With the exception of such substances as the monosaccharides, the body is unable to utilize foods until certain chemical changes take place permitting them to pass through the membranes of the digestive tract. The resulting materials (nutrients) which are absorbed and carried to the tissues are generally not unaltered constituents, but transformed chemical products arising from the action of the digestive juices on ingested

The so called crystalloid foods (p 110) are usually absorbed directly and unchanged, although the disaccharides such as sucross first undergo hydrolysis to monosaccharides (p 338) Colloidal foods, such as starch, proteins and emulsified fats, are, on the other hand, not generally directly absorbable. The digestive fluids must disintegrate them into simpler chemical compounds before they can diffuse through the intestinal walls into the blood stream

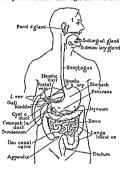


Fig 1—The Pathway of Food The diagram and cates all organs of this digestive system Why a food within the all mentary canal not considered to be within the hody?

Digestion is the process that takes place in the alimentary tract that results in the breaking down of complex foods into simple soluble compounds, whose molecules are small enough to pass through membranes and thus be absorbed by the cells of the body

# Digestive Fluids

In changing the less soluble components of food into more soluble ones the colloids are for the most part converted into crystalloids by a group of catalysts (enzymes) derived from living cells. These enzymes are manufactured by special cells in the salivary gastric pancreatic and intestinal digestive glands and are secreted as dilute solutions into the alimentary canal.

The chief chemical change involved in digestion is one of hydrolysis which is effected by enzymes in the acid or alkaline fluids secreted by the respective glands. In these hydrolytic changes, (a) the carbohydrates are changed to monosacchardes, (b) the fats to fatty acids and glycerol, and (c) the proteins to amino acids Since enzymes have so much to do with the reactions which take place in the body, not only during digestion but also in many of the activities of the living cells, it is important to gain a clear idea of these mysterious catalysts and of their functions

#### SELF-TESTING QUESTIONS

- 1 What are the chief functions of foods?
- 2 What foods are included under crystalloids and which under colloids?
  3 What is the purpose of digestion?
- 4 What are the digestive fluids?
- 5 What kind of chemical reaction is produced by enzymes?
- 6 What are the hydrolytic products of carbohydrate fat and protein digestion?

# II. ENZYMES AS CATALYSTS

# Nature of Enzymes

In the study of chemical reactions we have been presented with instances in which the time required for a reaction was greatly reduced by the addition of a trace of some material which remained unaltered during the change taking place. Such materials which influence chemical changes without undergoing a change them selves are called catalysts For example, in the chapter on carbo hydrates, catalytic action was involved when starch was hydrolyzed into glucose, and cane sugar was converted to glucose and fructose, by boiling the starch or cane sugar solutions with a few drops of hydrochloric acid, i e, by increasing the hydrogen ion concentra tion of the solutions In living bodies there is a great variety of chemical reactions produced in cells by organic catalysts These catalysts, known as "enzymes" or "ferments," although made only by living cells, can exist and function quite separately from the cells making them, i e, isolated enzymes can act as catalysts in test tube reactions The separation and purification of enzymes have met with great difficulty To date, however, several enzymes of a protein nature have been obtained in a crystalline form—urease, which decomposes urea into ammonia and carbon dioxide, pensin of the gastric nuce, and trypsin of the pancreatic nuce

# Nature of Enzyme Action:

Enzymes, as organic catalyzers, aid in regulating a large number of the chemical reactions in the body. Not only is digestion a series of enzyme reactions but practically all of the other chemical processes that occur in the living body are catalyzed by enzymes. In studying the chemical nature of enzymes it seems conclusive that enzymes are proteins, and that the special property of a given enzyme is due most likely to a specific active group or groups in the enzyme molecule. The exact mechanism by which an enzyme catalyzes a chemical reaction is not clear but it appears that a temporary chemical combination between the enzyme and the substance being digested occurs. One molecule of an enzyme can catalyze the reaction of a very large number of molecules of the substance being digested.

## Specificity.

Enzymes differ somewhat from inorganic catalysts in their action. The enzymes for the most part exhibit a marked selective action for some substances and for this reason are limited in their action. For example, the enzyme that changes starch into sugar does not change cane sugar into a simpler sugar, but both starch and cane sugar undergo these changes in the presence of almost any dilute acid. Each enzyme has its own special action on one particular kind of substance which is called the substrate and so far as known only one such action. The action of each enzyme is analogous to a key which unlocks only a particular door. Only a few morganic catalysts behave like enzymes in showing some degree of specificity.

#### Classification

Since the chemical differences of enzymes are unknown, we can only classify them according to the kind of chemical action they bring about, and name them according to the nature of the substance acted upon

For the different kinds of chemical changes produced by enzymes we have the following classes, (1) hydrolytic enzymes, which hydrolytic enzymes, which hydrolytic enzymes, which hydrolytic enzymes, which produce have a large molecule (carbohydrate, fat, protein, or derivative) and water to form smaller molecules, (2) fermenting enzymes, which produce fermentation, (3) oxidizing and reducing enzymes, which yield body energy by the addition of oxygen or the removal of

## CLASSIFICATION OF SOME IMPORTANT ENZYMES\*

Enzymes and Distribution	Chemical Change
Carbohydrases Amylases Salivary amylase (ptyalin) Pancreatic amylase (amy lopsun) Disaccharidases Sucrase Lactase Maltase	Starch → dextrns → maltose  Starch → dextrns → maltose  Sucrose → glucose + fructose  Lactose → glucose + galactose  Maltose → glucose + glucose
Lipases Gastric lipase Pancreatic lipase	Fat (emulsified) → fatty acids + glycerol Fat (emulsified) → fatty acids + glycerol
Proteinases Gastric proteinase (pepsin) Pancreatic proteinase (trypsin) Intestinal peptidases (erepsin)	Proteins proteoses peptones peptides amino acids  Peptones peptides amino acids
Zymase (yeast)  Lactic acid (lactic acid bacteria)	Monosacchandes → C2H5OH + CO2 Lactose → lactic acid
Oxidases Catalase Peroxidase	Decomposes H <sub>2</sub> O <sub>2</sub> to form O <sub>2</sub> Liberates atomic oxygen from organic peroxides, favoring oxidation
Deaminases Urease	Urea → CO <sub>2</sub> + NH <sub>2</sub>
Rennin (gastric juice) Thrombin (blood)	Casein → paracasein (milk clot) Fibringen → fibrin (blood clot)
	Carbohydrases Amylases Saluvary amylase (ptyalm) Pancreatic amylase (amy lopsin) Disacchandases Sucrase Lactase Maltase Lapases Gastric lipase Pancreatic lipase  Proteinases Gastric proteinase (pepsin) Pancreatic proteinase (trypsin) Lintestinal peptidases (erepsin)  Lactic acid (lactic acid bacteria) Oxidases Catalase Peroxidase  Deaminases Urease Rennin (gastric juice)

<sup>\*</sup> Hawk and Bergeim Practical Physiological Chemistry 10th ed., pp 235-6

hydrogen from the substances acted upon, (4) deaminizing enzymes, which release ammonia from organic amine groups, (5) cogulating enzymes, which produce coagulation of proteins such as rennin upon casein of milk

Each of the foregoing classes of enzymes is further subdivided into various members and named in accordance with the class of compound acted upon Thus each of the hydrolytic enzymes acts on a specific substance, such as the carbohydrates, fats, proteins and their decomposition products The ending ase to a word usually indicates an enzyme, and it is attached to the name of the substance that the enzyme acts on, called a substrate Thus, the starch (amylum) hydrolyzing enzymes are called amylases, the fat (lipid) splitting enzymes lipases, and the protein splitting enzymes proteinases When referring to a particular enzyme, it is customary to indicate its place of occurrence, eg. salivary amylase and pancreatic amylase Since some of the enzymes-pepsin and trypsin, ptyalin rennin-received names long before the adoption of the above mentioned method of classification, there has been some confusion and disinclination or failure on the part of many to adhere strictly to the adopted nomenclature

#### SELE-YESTING QUESTIONS

- 7 What is the function of an enzyme?
- 8 Name three crystalline enzymes and give the function of each.
- 9 What is the chemical nature of an enzyme?
- 10 What is meant by the specificity of an enzyme?
- 11 Upon what basis are enzymes classified?
- 12 What are the various classes of enzymes and what are their functions?

  13 What chemical change is produced by the hydrolytic enzymes on the
  - different carbohydrates on the fats and on the proteins?
- 14 How are enzymes named?

## III BEHAVIOR OF ENZYMES

### Properties of Enzymes

Although widely distributed in living material, enzymes exist in such small amounts that their separation is quite difficult. However, several enzymes have been isolated as pure compounds which are of a protein character. Within recent years it has been learned that certain of the B complex vitamins act as the specific active group (prosthetic group) of some of the enzymes that function in

cellular oxidation and reduction reactions Enzymes have certain properties in common As they are relatively large molecules, they are colloidal in water, in dilute alcohol and in aqueous sodium chloride solution, but are precipitated by ammonium sulfate and strong alcohol The large size of protein molecules accounts for the fact that enzymes do not readily diffuse through semipermeable membranes

Although the structures of most enzymes are still unknown, there is available considerable knowledge of the factors that influence their activity

# Effect of Temperature

Like most proteins, enzymes are very sensitive to heat and are inactivated at temperatures which coagulate protein (50° C to 80° C). On the other hand, it is known that as temperature is increased the rate of chemical reactions is greatly accelerated. This generalization holds true of reactions catalyzed by enzymes. Therefore, in an enzyme reaction two opposing effects of temperature are involved, one the effect of increased temperature in increasing the rate of reaction and the other the effect of increased temperature is that temperature at which an enzyme whibits its greatest activity. In general this temperature is usually a few degrees above body temperature. At lowered temperatures such as 0° C the action of an enzyme is greatly decreased or may be almost completely inhibited.

# Effect of Hydrogen Ion Concentration (pH or acidity or alkalinity).

In addition to this influence of heat, enzymes are sensitive to the nature of the medium in which they exist. Some enzymes function only in the presence of dilute acids, and some only in dilute akids, and some only in dilute akids, and some only in dilute akids ne or neutral solutions. This is particularly true of pepsin which requires for its optimum action on proteins a definite hydrogen ion concentration corresponding to 0 2 to 0 5 per cent. HCl, and above or below this approximate hydrogen ion concentration (pH of about 1 6) the action is inhibited. Trypsin on the other hand digests proteins in either a neutral or an alkaline medium (pH of 8 0), but is inactive in an acid solution. Furthermore, salivary amylase (ptyalin) is more active in a neutral than in either an acid or an alkaline medium, and is completely mactivated by the high bydrogen ion concentration of the gastric juice. There is an optimum

hydrogen ion concentration for maximum activity, the concentration depending upon the nature of the enzyme

# Coenzymes:

Certain enzymes show activity and function properly only in the presence of other substances, generally called coenzymes. In some instances the factors necessary are inorganic ions. Calcium ion, for example, is essential for the activity of the prothrombin of the blood, and chloride ion speeds the activity of salivary amylase Zymase of yeast requires the presence of phosphate ion. Such inorganic ions which are necessary for the functioning of certain enzymes are sometimes called activators.

Many active enzymes, particularly those involved in oxidations and reductions, have been found to consist of two parts, both organic, usually loosely bound together. One part, protein in character, is known as the apoenzyme, and the other portion a non protein, is termed the coenzyme or prosibilitie (helping) factor. In some cases these two parts can be separated by dialysis, and it is found that neither taken alone possesses enzyme activity. It is interesting to learn at this time that vitamins frequently enter into the structures of such coenzymes.

#### Zymogen.

The mactive state exhibited by certain enzymes is often referred to as the zymagen form or as the proenzyme. This mactive zymagen must be transformed or activated by certain specific substances (kinases) secreted by the cells. For instance, pepsinagen, the zymagen of the enzyme of the gastric juice, is activated by hydrochloric acid (secreted by the gastric cells) into pepsin, at a pH of 6 0 or below, and trypsinogen of the pancreatic juice is changed by enterokinase of the pancreatic cells into tryosin

# Enzyme Inactivation, Antienzymes

In decided contrast to coenzymes which are needed for enzyme action, there are many organic and inorganic substances which inactivate enzymes, either reversibly or irreversibly. The salls of heavy metals such as silver, mercury, copper and lead, and in fact all the protein precipitants, are particularly toxic to enzymes. Other more specific organic inactivators that are formed by living cells are referred to as antienzymes. Such antienzymes occur in the lining cells of the digestive tract where their presence prevents

the digestion of the protein which forms the walls of the stomach and intestine. Antienzymes are also present in the blood and there is a reasonable amount of evidence to indicate that in vivo clotting of blood is prevented by antienzyme action. Enzymes are mach vated not only by heat, unfavorable hydrogen ion concentration (pH), and antienzymes, but also by shaking and ultraviolet light

In a solution where enzyme action is occurring the activity of the enzyme usually decreases. This may be due to spontaneous decomposition of the enzyme or to the effect of accumulation of end products of the reaction. Enzymes do not change the equilibrium point of a reaction but merely cause the equilibrium point to be attained more rapidly. Therefore the speed of the reaction will decrease as the equilibrium point is reached.

### SELF-TESTING QUESTIONS

- 15 What facts seem to indicate the colloidal nature of enzymes?
- 16 What factors influence the activity of enzymes?
- 17 Illustrate by example what is meant by optimum temperature
- 18 What are coenzymes?
- 19 What is a zymogen?
  20 What are antienzymes?
- 21 How do salts of heavy metals mactivate enzymes?
- 22 What other substances mactivate enzymes?
- 23 How do enzymes as catalysts differ from inorganic catalysts?

### IV. THE DIGESTIVE FLUIDS

With some understanding of the nature of enzymes we are ready to consider the changes that foods undergo in the course of diges tion. To some extent this is a familiar story, since the physiology of digestion has been or will be presented in another course. As a consequence, the discussion in this chapter will be more concerned with the chemical factors involved in digestion.

# Cooking vs Digestive Processes

Before considering the different digestive fluids, attention is called to the fact that many processes involved in the preparation of food are somewhat similar to those of digestion Prolonged cooking in a slightly acid medium may partly hydrolyze starch and disaccharides into simple sugars. Moreover, cooking prepares raw starch food for more effective enzyme action in the body by rupturing the insoluble cellulose coating which surrounds the starch granules. Cooking converts the tough white fibrous connecting tissue (e.g., collagen) of meat into gelatin. In addition, the heat required to

### DIGESTIVE FLUIDS

Site	Secre tion	Enzyme	Substrate	Medium	Extent of Digestion	
Mouth	Salıva	Ptyalin	Starch	Usually slightly acid about pH 6 5	Slight	Dextrin maltose
Stomach	Gastric	Pepsin Rennin Lipase	Proteins  Casein  Fats (emulsified)	Normally about pH 16	Incom plete  Mostly complete Very slight	Proteoses and peptones Paracasein Fatty scids + glycerol
	Pancre-	Trypsin Chymo trypsin Carboxy pepti dase	Proteins Proteoses Peptones Peptides		Almost complete	Amino acids Amino
	atic	Amylopsın Steapsın	Starch Fats	About pH 78 05% Na <sub>2</sub> CO <sub>3</sub>	Almost complete Almost complete	maltose Fatty
Intestine	Intes-	Amino- pepti- dase Dipepti- dase Maltase	Polypep- tides		Complete Complete	acıds
	tinal Mucosal cells		Sucrose Lactose		Complete	Glucose + fructose Glucose + galactose
	Bile	No en zymes, action due to salts, etc	Fats			Emulsifies fats Promotes fat ab- sorption

cook foods, especially meats, destroys pathogenic microorganisms which in some cases may cause serious disturbances in the body Storage, too, brings about chemical changes in the composition of foods, and meats kept at certain temperatures become more tender through the action of the natural enzymes in the meat slowly changing and softening the structure of connective tissue that holds the muscle fibers together, a process taking place in from four to eight weeks \* Some fruits and vegetables kept in storage also ripen through the action of enzymes. It is quite evident, then, that the preparation of foods often corresponds to, or is supplementary to. digestive processes Cooking requires a much higher temperature to produce changes in food corresponding to those brought about by digestive enzymes at body temperature. This has at least one drawback Prolonged cooking is associated with partial or complete destruction of some of the vitamins, notably vitamin C (antiscor butic) and may destroy some of the delicate flavor of certain types of food However such a simple thing as putting a cover on the vessel in which vegetables are boiled excludes the air and conse quently prevents much destruction of vitamin C

# Salivary Digestion

The saliva is secreted by three pairs of large glands, the parotid, the submanilary, and the sublingual and includes the secretion of numerous small glands that are present in the liming of the oral cavity. Saliva contains over 99 per cent water and less than 1 per cent solids. The chief solid is much, which is a glycoprotein that renders the saliva viscous and ropy and accounts for its lubricating action. Other solids include the enzyme salivary amylase (ptyalin), and inorganic and organic substances that are derived from the blood. The inorganic salits of saliva have two important functions—the phosphates act as buffers that tend to maintain the reaction (pH) of the saliva constant, and the chloride ions are essential as coenzymes for the salivary amylase.

The flow of salva (about 1500 ml daily) is the result of stimula tion of the salvary glands by the nervous system, as is evidenced by the fact that actual contact with food is unnecessary since sight, odor, or even thought will cause the salvary glands to secrete profusely

<sup>\*</sup>The Tenderay Process Sterilamps accomplish this result in one to two days by keep ing the meat free from bacterial action of the air at a temperature of 60°F and a humidity of 90

Other factors which influence secretion are the nature and quantity of the foods eaten, and the thoroughness of mastication

SALIVARY AMYLASE OR PTYALIN is the principal enzyme of the saliva. This enzyme is capable of hydrolyzing cooked starch into dextrins and maltose

The maltose so produced is later hydrolyzed by intestinal maltase to glucose

Ås foods are usually masticated only for a relatively short time before they are swallowed very hitle digestion of starch takes place in the mouth Fortunately, salivary digestion may proceed for some time, 10 to 20 minutes or even longer, after reaching the stomach, owing to the time required for the food in the stomach to become mixed with the said gastric puice This said medium eventually inhibits any further action of the salivary enzymes. The main function, then, of the saliva is to begin hydrolysis of cooked starch into destrins and maliose. In addition, saliva keeps the mouth moist, and dissolves and lubricates some of the masticated food, whose juices stimulate the taste buds, thus making food more pulatable

## Gastric Digestion

The food upon passing through the esophagus enters into the fundus of the stomach, a hollow muscular pouch, whose lining is a soft mucous membrane arranged in folds. It is in these folds that the glands are found which secrete gastric juice (2000 to 3000 ml

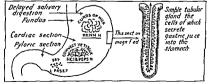


Fig 2—Where Gastric Juce Is Produced Over 2 000 000 tube I ke glands secreto gastric juce Where does the digest on of starch stop and that of protein bean if

daily), a thin, watery, strongly and (0 2 to 0 5 per cent HCl) solution Gastric juice contains gastric proteinase or pepsin, a protein splitting enzyme, rennin, a milk coagulating enzyme, and traces of eastric linase. a fat soluting enzyme (Fig. 2)

The gastric glands (fundus and pyloric), like the salivary glands, are stimulated by psychical and chemical action. The psychical form of stimulation is mainly pleasurable anticipation, which causes a rapid flow of gastric juice, while strong mental or physical activity, such as anger or excitement retards its flow. The chemical stimuli may be produced by certain substances, particularly the soluble extractives of foods. As the extractives of meat are quite effective in this respect we may understand the value of beginning a meal with a clear soup as an appetizer.

The formation of the hydrochloric acid in the gastric juice is closely associated with the parietal cells of the gastric glands. The chloride ions of the hydrochloric acid probably come from the so dium chloride in the blood and the hydrogen ions perhaps from some weak acid such as carbonic acid. One prevailing theory is that hydrochloric acid forms as the result of an interchange of ions be tween sodium chloride and carbonic acid, as indicated in the following equation.

Na+Cl + H+HCO3 ⇒ Na+HCO3- + H+Cl-

The concentration of the acid secreted is fairly constant (0 2 to 0 5 per cent). If the percentage of acid is below normal (hypo acidity) as may occur in perincious anemia and cancer of the stomach, digestion is retarded. Furthermore, in hypoacidity, there is less check on the growth of the microorganisms in the stomach. The hydrochloric acid is secreted largely after the food enters the stomach, and then it comes into contact with the food. Occasion ally, the secretion of hydrochloric acid is above normal (hyper acidity). In peptic ulcer patients there is often hyperacidity a condition closely associated with emotional strain and overwork.

PEFSIN or gastric proteinsse is produced as an inactive zymogen (pepsinogen) by the chief cells of the gastric glands. When the pepsinogen comes in contact with the acid produced by the parietal cells it is activated and converted into pepsin. This enzyme acts on most of the proteins of the ingested foods and converts them into soluble proteoses. Some proteoses may change to peptiones or even to higher polypeptides during gastric digestion.

Proteins Proteoses Peptones

This partial hydrolysis of the proteins in the stomach is of great importance in that the proteinses of the pancreatic and intestinal secretions are able to act more quickly and completely in furthering direction of the proteins in the small intestine

RENNIN is the enzyme in the gastric juice of young animals which splits the casein molecule of milk into two smaller molecules, called paracasein, each of which unites with a calcium ion to form insoluble calcium paracasemate. This insoluble formed protein digests more readily than colloidal casein and furthermore, prolongs the digestive action of pepsin, the chief proteinase of the stomach.

Attention is especially called to the fact that remain can clot milk in a neutral solution, an important property in the digestion of milk in inweaned babies. Curding of milk may also be produced by acids or by the action of pepsin

Gastric lipase a fat splitting enzyme, is of but slight importance, largely because of the presence of hydrochloric acid, which is un favorable for the emulsification of fat and the action of the enzyme Some fatty acids and glycerol are probably formed as the result of the hydrolysis of emulsified fats such as those occurring in milk and egg yolk.

In two or three hours the combined effect of the proteolytic enzyme, hydrochloric acid, and the churning of the wavelike contractions of the stomach convert the food into a thin watery liquid, called *chyme* It is in this way that muscle fibers and the connecting tissues of meat (in the presence of acid) absorb sufficient water to cause them to swell, soften and become more accessible to further digestion by the enzymes

Following the action of the enzymes and the formation of chyme, peristaltic contractions propel this material forward toward the pylorus Succeeding peristaltic waves force this semiliquefied food through the opening of the pylorus into the small intestine. The acid is immediately neutralized by alkaline intestinal juices, reflexes occur, and the pyloric opening closes. Recent opinions on the discharge of food from the stomach seem to favor the view that many factors control this process rather than that either the hydrochloric acid or the state of the digestive products alone governs the section.

# Intestinal Digestion:

The liquid food (chyme), upon leaving the stomach, enters the duodenum which is the first 11 or 12 inches of the small intestine From a digestive standpoint the duodenum is the most important part of the intestine. Here, the chyme is acted upon by three



Fig 3—Avoiding Guesswork. Doctor fluoroscopes patients digestive tract with aid of x ray umit. What salt mokes this examination possible? Courtesy, General Electric Co.

juices the bile, the pancreatic juice, and later, by the intestinal juice (succus entericus). The acid chyme is neutralized on entering the intestine and when the food is sufficiently alkaline the action of the digestive enzymes of the intestinal juices begins. The acid food upon contact with the intestinal mucosa reacts with prosecretin elaborated by the duodenum cells to form secretin, a hormone which enters the blood stream and stimulates the pancreas to secrete the PANCREATIC JUICE This secretion (500 to 800 ml daily) is a

clear, watery, alkaline (pH 75 to 8 or 05 per cent Na<sub>2</sub>CO<sub>3</sub>) solution, much like saliva, but far more important than either the salivary or the gastric secretions Pancreatic fuice contains several important enzymes trypsin, a protein splitting enzyme, chymo trypsin, a milk clotting and protein splitting enzyme, carboxypep tidase, which hydrolyze peptides to amino acids, amylopsin or pan creatic amylase, a staich splitting enzyme, and steamsin or pan creatic lipase, a fat splitting enzyme

1 Trypsin or pancreatic proteinase appears in its mactive form (trypsingen), which is readily converted into the active trypsin by a substance called enterokinase According to the present view, enterokinase is an enzyme that occurs in the secretion of the walls of the duodenum, acts upon trypsingen as a substrate, and con verts it into trypsin Trypsin is an important enzyme of the pan creatic juice, and is much more effective than pepsin upon the proteins, because trypsin not only catalyzes native protein hydrol vsis, but also continues the hydrolytic process to the amino acid stage

Proteins → proteoses → peptones → polypeptides → peptides → amino acids.

- 2 Chymotrypsin is secreted in the pancreatic juice as an inactive zymogen, chymotrypsinogen, which is activated in the duo denum by trypsin The active enzyme has an action very similar to trypsin but in addition has a powerful milk clotting activity
- 3 Carboxypeptidase This peptidase of the pancreatic juice catalyzes the hydrolysis of certain peptides to amino acids
- 4 Amylopsin or pancreatic amylase, the starch-splitting en zyme, has an action similar to salivary amylase (ptyalin) Amylopsin not only changes any starch incompletely acted upon by salivary amylase into maltose, but it is capable of digesting uncooked atarch

## Starch → dextrins → maltose

 Steapsin or pancreatic lipase, the most important fat-splitting enzyme, has the power of hydrolyzing neutral, emulsified fats to glycerol and insoluble fatty acids.

$$\begin{array}{lll} \textbf{C}_3\textbf{H}_5 \cdot (\textbf{C}_{18}\textbf{H}_{35}\textbf{O}_2)_3 + 3\textbf{H}\textbf{O}\textbf{H} \rightarrow 3\textbf{H} \cdot \textbf{C}_{18}\textbf{H}_{35}\textbf{O}_2 + \textbf{C}_3\textbf{H}_5(\textbf{O}\textbf{H})_3 \\ & \text{(insoluble stearns} & \text{(glycerol)} \end{array}$$

There is no marked difference between the digestibility of animal and vegetable fats. The percentage of digestibility of edible fats follows: vegetable fats 97.1 per cent, butter and lard 97 per cent, animal fats 96 per cent, and hydrogenated vegetable oils 93.5 per cent. The emulsification of fat and the consequent hydrolysis of the fats are greatly accelerated by the bile salts.

INTESTINAL JUICE: The intestinal juice represents the combined secretion of the glands which line the walls of the small intestine. It was formerly believed that this secretion had a strong digestive action since preparations of ground intestinal mucosa possessed powerful disaccharide splitting enzymes and also peptidase activity. However, at present, authorities feel that these enzymes are located inside of the cells of the intestinal wall and are never present in appreciable amounts in the secretion of the intestine. The digestive action of these enzymes is exerted as food passes through cells of the intestinal wall in the process of absorption. The disaccharide splitting enzymes include sucrase, maltase and lactase which catalyze the following reactions:

Sucrose 
$$+ H_2O \xrightarrow{\text{Moltose}} \text{Glucose} + \text{Fructose}$$

Maltose  $+ H_2O \xrightarrow{\text{Lockase}} \text{Glucose} + \text{Glucose}$ 

Lactose  $+ H_2O \xrightarrow{\text{Lockase}} \text{Glucose} + \text{Galactose}$ 

The completion of protein digestion is also accomplished by the action of several intracellular peptidases (known collectively as erepsin) which include at least two different enzymes, aminopeptidase and dipeptidase. The end products of protein digestion are amino acids.

The fact that the secretion of the intestinal wall does not contain large quantities of enzymes should not be reason to regard it as unimportant since it also has an important function in neutralization and lubrication.

#### SELE\_TESTING OUESTIONS

- 24 Name the salivary glands
- 25 Discuss the composition of saliva
- 26 What produces a flow of saliva?
- 27 Name the salivary enzymes and their functions
- 28 Name and state the function of each enzyme in the gastric juice
- 29 How does hydrochloric acid of the gastric juice influence digestion?
  30 What is chame?
- 31 What is the function of secretin?
- 32 Name the pancreatic enzymes and their functions
- 33 What is the function of each intestinal enzyme?

#### Bile

Bile is a viscous vellow to brown, bitter tasting alkaline fluid. that is secreted (500 to 800 ml daily) by the liver and flows via the bile ducts into the duodenim. The rate of secretion and of flow of bile is influenced by the nature of the food undergoing digestion. the stimulation probably being influenced by a hormone, secretin, Many salts such as Epsom salts stimulate the flow of bile. In the absence of food, most of the bile is diverted to the gallbladder (about 30 ml capacity) where it is stored and becomes concentrated to one tenth its previous volume by lymphatic reabsorption of water, salt, cholesterol, and pigment from it and by the addition of mucin, a secretion from the wall of the gallbladder. During active digestion the contents of the gallbladder are evacuated into the duodenum and thus provide a concentrated supply of bile The bile may also be considered an excretion, since it eliminates. as waste products of cellular action, certain substances which it alone can dissolve (e g. cholesterol) In addition to the lipids, mucin, and bile pigments, bile contains certain salts, the importance of which will be discussed

The following table shows the common constituents in bile

Secretion Components	Excretion Components
Bile salts Sodium bydrogen carbonate Water	Bile pigments Cholesterol

THE BILE SALTS OR BILE ACIDS Although bile contains no digestive enzymes it plays an important role in the digestion and absorption of fat and indirectly that of other foodstuffs As it is

alkaline, the bile along with the pancreatic juice and intestinal juice neutralizes the acid chyme from the stomach. As already mentioned the bile contains a type of compound called bile salts or bile acids. The two most important of these substances are sodium glycocholate and sodium taurocholate. A most important property of the bile salts is that they act as wetting agents by lowering surface tension of water, and in so doing give greater penetration, and facilitate the emulsification of fat. In the absence of adequate emulsification very little fat digestion by pancreatic lipase (steapsin) occurs in the intestine.

In addition the bile salts play an important role in fat absorption by uniting with the insoluble fatty acids, liberated from fats by inase action, to form soluble compounds known as choleic acids. These choleic acids upon absorption separate again, and the fatty acids unite with glycerol in the lymphatic vessels of the vill (acteals) to form fats which are transported by the lacteals to the thoracic duct and eventually to the blood stream. The liberated bile salts are then available for further use by the liver. They are resecreted into the bile and thus undergo a type of circulation—

1 e, from blood, to liver, to bile, to intestine and back to blood

The bile salts possess the property of stimulating the secretion of bile and as such can be regarded as cholagogues (substances stimulating the flow of bile). They also aid peristalsis. In the absence of adequate bile flow extensive putrefaction of protein occurs in the lower portion of the gastrointestinal tract. This is due in part to the decreased peristalsis and in part to the undigested fat which forms an only film over protein particles and retards their digestion. Thus the absence of bile causes serious disturbances of intestinal digestion and absorption. The feces contain greatly increased quantities of fat and may be clay colored and greasy, and have a very foul odor. In some cases constipation may result from decreased peristals is

THE BILE PIGMENTS These consist mainly of bilirubin and biliverdin, mostly\* formed when the liver salvages "organic iron" from the blood pigment (hemoglobin) of worn out red blood cells In this decomposition of hemoglobin into globin and hematin, the latter, with loss of iron, changes into bile pigments which impart a yellow to brown color to bile Bilirubin has a reddish cast, while its oxidized product, biliverdin, is a green pigment Normally

<sup>\*</sup>Bile pigments may be formed in other tissue, c. g., spleen, bone marrow lymph glands

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there is little or no biliverdin in the bile but on exposure of bile to air it will turn green because of oxidation of bilirubin to biliverdin Oxidation produces a series of colored compounds, including bili cyanin, a blue pigment. The series of colors in bruised ekin is un doubtedly due to the decomposition of the hemoglobin liberated by injured red cells which exuded from the capillaries of the injured tissue. Obstruction to the bile ducts, disease and dysfunction of the liver or an abnormal destruction of the red blood cells will result in an increased amount of bilirubin in the blood. This will diffuse into the skin and mucous surfaces and will give them a characteristic yellow color which is known as jaundice or reterus

In the intestines, the reducing bacteria change bile pigments in part to sterobilin, a brown pigment, which accounts for the char acteristic color of feces. Some urobilin is also formed, and a part of the yellow color of urine is due to this pigment. It is of secondary importance to another yellow pigment in urine called urochrome. Too frequent elimination (diarrhea) does not allow for much reduction of bile pigments with the consequence that feces then have a decided yellow instead of a brown color, the color depending somewhat on the cause of the diarrhea.

CHOLESTEROL This important excretory compound of the blie is ordinarily soluble in bile. However, in the presence of foreign substances, such as injured cells or bacteria, the cholesterol tends to crystallize, carrying with it some bile salts and pigments to form gallstones. It may also play a part in arteriosclerosis Cholesterol is an alcohol (C<sub>2</sub>:H<sub>4</sub>;OH) and like glycerol (C<sub>2</sub>:H<sub>4</sub>;OH), unities with fatty acids to form esters but it differs in that its esters do not easily sapomly. When cholesterol deposits on the inner sur face of blood vessels, hardening of the arteries occurs Landin, the fat of sheep's wool, contains the stearic, palimitic, and oleic acid esters of cholesterol.

#### SELF-TESTING QUESTIONS

34 What is bile?

35 What stimulates the flow of bile?

36 Why may bile be called an excretion?

37 What are the functions of the bile?

38 How does the absence of bile affect digestion?

39 What are the two chief bile pigments?

40 What are the functions of sodium glycocholate and sodium tauro cholate?

## V. BACTERIAL DIGESTION AND ABSORPTION

### Bacterial Action in the Colon:

Following intestinal digestion any undigested, unabsorbed food is forced into the large intestine, or colon, where it is subject to the action of bacteria. A small amount of material may be absorbed here, but there are no secreting glands to produce further digestion.

Ordinarily, most of the bacteria in food are killed by the acid chyme of the gastric juice. However, upon reaching the more alkaline fluids of the intestine, neutralization of the acid takes place and a medium favorable for the growth of bacteria is produced. Normally in the lower part of the small intestine and in the large intestine an enormous number of bacteria are found. Some idea of the number can be imagined when it is realized that more than one fourth of the weight of dried feces consists of dead bacteria.

There are many kinds of bacteria in the colon and the chemical changes which occur depend largely upon what material they act upon. In other words, diet may regulate intestinal putrefaction. For instance, to reduce putrefaction the amount of protein is reduced and carbohydrates are increased. Whenever this is done the bacteria act upon the carbohydrates to produce acids which are unfavorable to putrefaction. Advantage is taken of this fact in the use of buttermilk, sour milk, and acidophilus milk to reduce in testinal putrefaction. To reduce fermentation, proteins are largely substituted for carbohydrates. In this way, very little undigested carbohydrates reach the colon for the action of the fermentative bacteria. Ordinarily, the greater the cellulose, hemcellulose, etc., content of the diet, the greater will be the amount of indigestible carbohydrate residues reaching the colon.

Of recent and decided interest is the discovery that bacterial action depends largely upon the medium, and if the medium contains sufficient carbohydrates, no toxic putrefaction products are formed. For instance, the diphtheria germ in the presence of sufficient lactose merely changes lactose into lactic acid, but in the absence of certain carbohydrates, the same bacterium develops the dread diphtheria toxin.

Carbohydrates are readily attacked by certain bacteria to form relatively nontoxic substances, such as acids (lactic and the lower tatty acids of the butyric acid type), alcohol, and gases (CO<sub>2</sub>, CH. H<sub>2</sub>) Cellulose, such as that of young celery, is acted upon to some extent by bacteria to produce compounds, which may be absorbed

Bacteria in the intestine perform the useful function of decomposing indigestible residues and perhaps in aiding the synthesis of certain water soluble vitamin; notably the B vitamins Quantities of vitamin K sufficient to meet the needs of the body are also synthesized by intestinal bacteria

Fals do not appear to be acted upon by bacteria, or at least not to any appreciable extent. It is possible that some fatty acid and glycerol may be formed by bacterial decomposition of fats

Protein decomposition by bacteria yields amino acids, which further decompose by first spilting off ammonia (deaminization) and then carbon dioxide (decai boyylation) to form certain phenols from aromatic amino acids, or the amino acids may only split off carbon dioxide and immediately produce more toxic amines. His tamine, phenol, indole and skatole are some of these decomposition products the latter two contributing to the characteristic and disagreeable odir of feces.

The derived phenols acids and amines resulting from bacterial action are toxic when absorbed in excess of the amount that can be detoxicated by the liver and eliminated via the kidneys as harmless compounds Hitherto, the prevailing opinion was that during con stipation these putrefaction products are absorbed and are re sponsible for such ills as headaches, irritability, and general malaise. This does not seem entirely warranted in the light of experimental evidence These autointoxication symptoms may be produced by abnormal distention of the lumen of the rectum as when the rectum is packed with cotton The acceptance of this statement seems to be warranted when we consider that evacuation of the colon following constipation gives relief from these symp toms in certain uncomplicated cases. The prompt relief within a few minutes following evacuation suggests that the disturbance was partly of a nervous origin. Eliminating the toxic materials from the body would require a much longer time

These observations along with the recognition that certain important vitamins may be synthesized and contributed to the body's economy by intestinal bacteria have caused a considerable shift in attitude regarding the usefulness or harmfulness of intestinal bacteria. In general at the present time it is felt that they do perform useful functions and that it is only when there is a disturbance of function or a diseased state that they produce undesirable effects

# Absorption:

No absorption of food takes place in the mouth and but very little from either the stomach or the colon. From the colon, water and some salts are absorbed, the absorption of the water accounting for the consistency of the feces. Practically all absorption of food takes place in the small intestines, which are particularly well adapted for this purpose by reason of their great length (about 25 feet), because of the long time foods remain in the intestine (about five hours; sometimes several days), and the large exposed surface (about 100 square feet).

The vascular projections in the intestinal walls are known as villi. They afford an extraordinarily large surface, and, with their rich and rapidly circulating supply of blood and lymph, they permit quick absorption of digested food materials (Fig. 4).

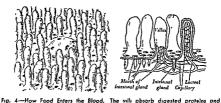


Fig. 4.—How Food Enters the Blood. The vill absorb digested proteins and carbohydrates. Digested for enters the lacteols and lymph. If each villus were a pit, like an intestinal gland, how would the rate of absorption be altered? From "Biology for Today," Ginn & Co.

Carbohydrates, as monosaccharides, are readily absorbed and carried by the blood to the liver. Here they are largely converted to liver glycogen which as a reserve of carbohydrate gradually breaks down to maintain constant levels of blood sugar.

Fats, as already mentioned, are emulsified and hydrolyzed to form fatty acids and glycerol, the glycerol being readily absorbed in the epithelal cells of the villi, while the insoluble fatty acids are probably absorbed as complex compounds (choleic acids) formed by the addition of bile acids and fatty acids. The glycerol and fatty acids reunite to form fats, which pass from the epithelial cells to the lacteals, and in lymph to the blood, and thence to the tissues Proteins are absorbed in the form of amino acids. A part of the amino acids is used to build tissue protoplasms and a part is oridized to urea, carbon dioxide, and water with the formation of energy. Before amino acids are oxidized they must first be deaminized (pp. 417, 521); this process of splitting off ammonia takes place in the liver. It sometimes happens that traces of unchanged proteins (native), and probably partly decomposed proteins, are absorbed from the intestines following the ingestion of certain foods which act immunologically on the system. Such food idiosyncrasies are peculiar to certain individuals, and often follow the eating of strawberries, eggs, and certain other food proteins. Sensitiveness to food proteins has been held responsible for some forms of allergy,\* including asthma, and certain skin eruptions

SUMMARY OF FOOD ABSORPTION

Food	Absorba ble Food Com-	Place of Absorption	Roule in Circulation	Food Products Carried by
	pound			the Blood
Carbohy- drates	Monosac- charides	Blood vessels of villa Rec- tum or any part of the gut as in in- testinal ob- struction	Blood of portal vein to the liver	Glucose (part of the glucose ab- sorbed and that formed from the fructose and galactose is changed by the liver into glyco- gen Other tis sues may form glycogen)
Fats	Glycerol Fatty acids	Epithelial cells of villi	Lacteals to lym phatics, to left thoracie duct, to blood	Emulsified fat, the absorbed glycerol, and fatty acids having been reunited in the cells of the mucosa
Proteins	Amino acids	Blood vessels of villi	Blood of the por- tal vein to the liver and to other tissues	Amino acids

<sup>\*</sup>Allergies are unusual reactions to any substance They may be caused by for: of infection, by the foods we eat, or by things we touch or inhale. Also allergy patients may become senantive to intungible agents such as guilpith test, cold and pressure

Inorganic salts, especially those containing sodium, potassium, and chloride ions are readily absorbed through the intestinies, but some ions such as magnesium and sulfate ions undergo very little absorption, and are more likely to withdraw water from the tissues by osmosis, a fact emphasized in the laxative action of Epsom salts (MgSO<sub>4</sub>)

The absorption of calcium and phosphorus ions is largely due to the presence of the antirachitic vitamin D

# The Feces

The gastrointestinal tract represents a pathway of excretion for the body. It has already been mentioned that bilirubin and cho lesterol are excreted into the intestine through the bile. In addition a certain amount of excretion of waste substances is carried out by the mucosa of both the small intestine and the large intestine. The feces also contain undigested, indigestible, and unabsorbed food residues along with residues of the gastrointestinal secretions (digestive juices). The waste substances of food include indigestible cellulose from carbohydrates, undigested connective tissue from meat proteins and undigested fats. This complex mixture provides an ideal medium for the growth of microorganisms and actually in the cecum and colon are found enormous numbers of bacteria of various types. It has been estimated that as much as half of the bulk of the stool may be due to the bodies of dead and living bacteria.

The composition of the feces will vary greatly depending on the ratio of the various constituents mentioned. In diseases of the pancreas and liver, where there is a deficient flow of pancreatic juice and bile digestion in the intestine is impaired and large quantities of fat and protein appear in the stool

Normally there is no blood in the stool but if a lesion is present in the gastrointestinal tract, blood can usually be detected If the bleeding is in the lower colon or rectum the blood can be recognized as such. However, if the bleeding is higher, such as may occur in peptic ulcer or in carcinoma of the intestine, the blood is altered and is referred to as occult (hidden) blood. If the quantity of occult blood is large the stools will have a black, tarry appear ance which is quite characteristic but if the amount is small it is necessary to employ a chemical test (such as the benzidine test) for the identification of the blood.

#### SELF-TESTING QUESTIONS

- 41 What action takes place when food enters the colon?
- 42 Does digestion take place here? Explain
- 43 How is the putrefying action of bacteria reduced?
- 44 The production of acids in the colon has what effect?
- 45 What products are formed by bacteria acting upon carbohydrates?
- 46 How do bacteria act upon proteins?
- 47 What is the effect of the absorption of putrefactive products?
- 48 What may cause symptoms of autointoxication? 49 What is the relation between carbohydrates and toxic putrefactive
- products?
- 50 In what way may cellulose be made available to the body?
- 51 Where are foods absorbed?
- 52 What happens to the carbohydrates after absorption?
- 53 In what form are fats absorbed?
- 54 What is the effect produced by the absorption of protein (unchanged protein)?
- 55 What components of foods resist digestion?
- 56 What significance is attached to finding large quantities of fat and protein in the feces? of blood?

### SUGGESTED ACTIVITIES

- I THOUGHT PROVOKING QUESTIONS
  - 1 The fact that enzymes are mactivated by alcohol salts of heavy metals and heat shows what classification of an enzyme? 2 What is there about the nature of sugars and mineral salts which
  - permits them to be absorbed directly while starches fats and proteins must be changed in order to be absorbed? 3 Why does it require a much higher temperature to oxidize sugar
  - outside the body than it does inside? 4 How does the appearance of food indirectly aid digestion?
  - 5 Enumerate the possible functions of hydrochloric acid in the
  - stomach 6 What useful purpose do the bacteria in the colon serve?
  - 7 Why are the small intestines well adapted for the absorption of

  - 8 Where and in what forms are the various foods absorbed?
  - 9 In what forms are the foods carried by the blood? 10 In what ways does trypsin differ from the action of pensin penti
  - dases from pepsin and amylopsin from ptyalin? 11 What hydrolytic changes in foods are produced by the digestive
    - fluids? 12 How are the bile salts supposed to function?
  - 13 What conditions may cause bile constituents to be increased in the blood?
  - 14 How do you account for the series of colors in a bruised skin usually called 'a black and blue spot ?

15 Considering that milk contains lactose, fat, the proteins, water, and morganic salts, state the action which takes place in the passage of milk along the alimentary canal

II V

VOCABULARY TE	STING OF NEW T	l'erms	
enzyme	digestion	hormone	steapsin
coenzyme	ptyalin	trypsin	peptidase
antienzyme	pepsin	enterokinase	bile
zymogen	rennın	amylopsın	cholesterol
apoenzyme	secretin		

- III TOPICS FOR ORAL OR WRITTEN REPORTS
  - 1 The Chemical Makeup of the Body Cells
  - 2 Enzymes as Catalysts
  - 3 The Nature of the Body Enzymes

### LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on pages 735, 737, 739

### THE CHEMISTRY OF BLOOD AND LYMPH

#### CHAPTER OUTLINE

- 7 Broom
  - (a) Characteristics of blood
  - (b) Functions of blood (c) Composition of blood
- II FORMED ELEMENTS
  - (a) Erythrocytes or red cells(b) Leukocytes or white cells
  - (c) Platelets
  - (d) Clotting of blood
- III ACID BASE BALANCE OF THE BLOOD
  - (a) Constancy of blood reaction (b) Hydrogen ion concentration
    - pH (c) Proteins as buffers
- IV BLOOD CHEMISTRY
  - (a) Tests for blood
  - (b) Blood groups and transfus on
  - (e) Rh factor in blood
  - (d) Collection and preservation of blood
- \_\_\_\_

- (e) Blood analysis as an aid in di agnosis and prognosis
- V PLASMA
  - (a) Function of plasma(b) Function of the plasma
  - proteins
    (c) Other plasma constituents
- VI FUNCTIONS OF THE BLOOD
  - (a) Transportation of nutrients and oxygen
    - (b) Transportation of waste products
    - (c) Transportation of hormones (d) Diffusion of heat
    - (e) Defensive action of the blood (f) Other blood constituents
    - (r) Uther blood constitue (g) Tissue oxidation
- VII EXTRACELLULAR WATER AND LYMPH
  (a) Functions of lymph
- (a) Functions of lymph
  VIII Antibiotics and Sulfa Drugs

### BLOOD

### Characteristics of Blood

Blood is a bright red fluid slightly heavier than water, average specific gravity 1 060, and faintly alkaline (pH 735). In the arteries it has a scarlet cast and in the veins a purplish hue. Approximately 1/10 of the body weight is blood, some variations occurring in pathological conditions. For instance, an increase in colume (plethora) is associated with polycythemia (pole is the me ah), chlorosis (klo ro'sis), and in some cases of anemia, but a decrease occurs in infantile diarrhea, absence of drinking water, fevers, severe burns, shock, intestinal obstruction, and in the inhalation of poisonous gases.

## Functions of Blood:

Blood acts to a large extent as the transportation system of the body and its five chief functions are

- 1 To transport nutrients and oxygen to the cells
- 2 To carry waste products from the cells to the organs of excretion

- 3 To transport the internal secretions (hormones)
- 4 To distribute heat and regulate body temperature
- 5 To aid in defending the body against invading disease germs

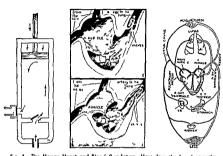


Fig. 1—The Human Heart and Blood Circulation. How does the heart operate much like a mechanical pump<sup>2</sup>. Note The term atrium has succeeded the term auricle. Courtery of New Worder World.

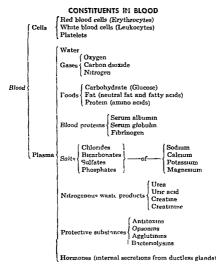
# Composition of Blood

The composition of blood varies somewhat, but it contains approximately the following constituents

	Water 78%		
		Proteins	18 5 %
Blood Solids 225	}	Glucose	01
		Lipids (fats)	14
	{	Salta (inorganic)	15
	•	Waste products etc	0.5

Whole blood consists of a liquid portion called the plasma in which are suspended cells or "formed elements" known as the erythrocytes, or red corpuscles, the leukocytes, or the white cor puscles, and the platelets The plasma, then, is the blood minus the formed elements. In the clotting of blood a soluble protein, called

fibrinogen, changes into the insoluble protein, fibrin, in which are enmeshed the corpuscles Upon contraction of the blood clot, a clear, slightly yellowish liquid, the serum, separates Serum then is essentially plasma minus fibrinogen. The following table shows most of the constituents in blood.



### SELF-TESTING QUESTIONS

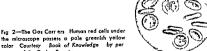
- 1 What are the chief functions of the blood?
- 2 What are the colors of arterial and venous blood?
- 3 What proportion of the body weight is blood? How does blood react to indicators?
  - 4 State five important constituents of the blood
- 5 What is the distinction between whole blood plasma and serum?

#### II. FORMED FIRMENTS

Suspended in the plasma are three types of formed substances or cells which make up slightly less than one-half the volume of human blood erythrocytes, the oxygen carrying cells, leukocytes, the disease resisting cells. platelets, indispensable for the blood clotting These cellular substances (corpuscles) may be separated from the plasma by sedimentation, or by centrifuging, and since the corpuscles differ in their density, the major portion of the red corpuscles which are heavier will occupy a layer below the white corpuscles, which have a lower specific gravity

# Erythrocytes or Red Cells.

The red corpuscles normally number approximately 5,000,000 per cubic millimeter in men and slightly less in women. This number may vary greatly under different conditions, such as altitude, exercise, starvation, drug administration, disease, etc Under the microscope, the red cells appear as circular biconcave discs, whose form changes somewhat in the small capillaries (Fig. 2). They have no nucleus, except when found in the bone marrow in the formative stage The span of life of the red cells is rather short. and a significant number are destroyed daily. Some chemical change apparently takes place rendering them less resistant to destruction, until at the end of from 60 to 120 days, they wear out and are destroyed by the reticulo endothelial system which is made un of phagocytic cells in the spleen, liver, and bone marrow. This indicates the necessity for repeated blood transfusions in some nathological conditions in which the normal formation of new red blood cells by the bone marrow is decreased, resulting in severe anemia



the microscope possess a pale greenish yellow color Courtesy Book of Knowledge by per m as on of the Grol er Soc ely

The principal characteristic of the red cells is the red coloring matter, hemoglobin, which is a combination of the protein, globin, and an iron compound, called hematin. The main function of the hemoglobin is to combine with the oxygen in the lungs and release part of it again to the tissues.

Hemoglobin + Oxygen 

Oxyhemoglobin

Hb O₂ HbO₂

During respiration, atmospheric oxygen in the lungs diffuses through the walls of the alveoli, and combines with the hemoglobin to form oxyhemoglobin (HbO2), the bright red (scarlet) substance in arterial blood. As the blood circulates through the capillaries in the various tissues, the oxyhemoglobin gives up its oxygen which is used by the tissues for oxidation. Upon this loss of oxygen by the oxyhemoglobin, the resulting hemoglobin imparts a dark red color to the blood, and when seen through the skin has a purplish cast (venous blood). Simultaneously, in the tissue capillaries, excretory products are taken up, chiefly carbon dioxide. which exists mostly as carbonic acid and sodium bicarbonate, a small amount only being combined with the blood proteins. The venous blood combines with this carbonic acid and thus carries the carbon dioxide to the lungs where it is exchanged for oxygen. This cycle is constantly going on and represents the basic process of respiration.

The preceding chemical transformations which occur during respiration are of very great importance, and are more complicated than the above statements indicate. It is the supply of oxygen that makes possible tissue oxidations which are the source of all energy needed by the body, not only for heat formation, but also for the building up and functioning of the tissues. This is especially noticeable in the brain cells where lack of oxygen causes giddiness and fainting spells. A total absence of oxygen, of course, quickly results in death.

The number of red cells varies under different conditions, and the hemoglobin content of each cell may also vary. Blood which contains an increased number of red cells (polycythemia) may impart a brick red color to the skin. On the other hand, a reduced number of these cells (anemia) gives a sallow and bloodless appearance to the skin. This latter condition may result from (1) hemorrhage; (2) failure by the body to manufacture blood; (3) ex-

cessive destruction of red corpuscles by toxins-poisons resulting from chronic suppurating sores or malignant growths or parasites. such as malaria in the blood and certain intestinal worms. With the exception of pernicious anemia, most anemias are treated by dietary measures. It has been shown that pernicious anemia may he controlled by the consumption of certain organ extracts, especially liver extract These extracts of liver and stomach contain some substance that acts on the bone marrow to form red cells and effective control of permicious anemia can be accomplished by the injection of liver extract. On this basis permicious anemia is a deficiency disease. The lack of hydrochloric acid in the stomach of those having permicious anemia suggests that this disease may he caused by some disturbance in pastric direction. Two of the B complex vitamins, folic acid (Lactobacillus casei factor) and vitamin Bio, are effective in the control of pernicious anemia Vitamin Bin is the active principle in liver extract

Before leaving the discussion of the red cells we must not forget the fact that they undergo hemolysis (p 103) when diluted with water or treated with a variety of substances (fatty acids, bile acids, snake venom, ether, chloroform, soap, etc.) In some cases, the hemolytic change is so slight that the distended membrane does not burst, but nevertheless allows for the passage of the hemoglobin from the red cornuscless into the plasma.

# Leukocytes or White Cells.

The white cells, of which there are several forms, number about 6000 to 8000 per cubic millimeter. They are larger than the red cells and have a nucleus. Blood which contains an extremely large number of white cells may appear creamy, this pathological condi tion is known as leukemia. Bacterial infection may produce a significant increase in the number of white cells White blood cell counts are used to assist the physician in detecting infection. The white cells are capable of ameboid movement, and consequently may leave the blood and enter the tissues Injury to the cells or infection resulting from bacteria, immediately causes a migration of leukocytes to the infected part where they engulf irritating par ticles, ingest and destroy the bacteria and degradation products of diseased tissues and cells This power of white blood cells to destroy bacteria is partly due to enzymes which they contain Because these white cells take up debris and bacteria, they are often referred to as "the scavengers of the body ' Scavenger cells

or phagocytic cells also are present in most tissues. When the tissue cells are injured or infected by bacteria, the condition that results is known as inflammation. The first evidence of inflammation is a dilation of the blood vessels, a slowing of the blood stream. Then the leukocytes migrate to the irritated or infected portion and engulf the irritating particles or the bacteria. In some cases of infection, the number of bacteria is so large that many white blood cells are destroyed by the bacterial toxins with the result that their dead bodies comprise a large part of the pus formed.

White cells are produced in lymph nodes, in bone marrow, and in the spleen. In all cases of inflammation, the red appearance of the part involved indicates the presence of a large number of red blood cells, the swelling points to the presence of an excessive amount of blood and lymph, the heat shows that blood has been brought from the deeper structures of the body, and the accompanying pain indicates the pressure of the inflamed tissue and the effect of toxins upon the nerves

# Platelets:

The platelets numbering about 300 000 per cubic millimeter are smaller then either the red or white cells, and appear as round or ovoid colorless discs. They are not true cells, and little is known about them, but their origin is believed to be in the bone marrow. Upon injury to the blood vessel wall, interference with circulation, or loss of blood, the number of platelets in the blood increases, a fact which suggests that they may, perhaps, have some relation to the white cells. The main function of the platelets is to assist in the changing of soluble fibrinogen to insoluble fibrin in the clotting of blood.

# Clotting of Blood

To prevent loss of blood from the body through mechanical in jury to the blood vessels, the blood itself has a way of changing from a fluid into a jellylike solid on contact with injured tissue According to one theory, blood contains prothrombin, which in the presence of calcium ions forms thrombin. The thrombin, in turn, changes the soluble fibringen (protein) into insoluble fibring.

According to most authorities the mechanism is also dependent upon an activating substance yielded by the platelets, and the platelets are active only when injured As the fibrin separates from the blood into a network of delicate threads, it holds the formed elements, chiefly red cells, within its meshes to form a jellylike solid called the blood clot. If the clotted blood stands, contraction of the fibrin fibers takes place and causes a pale yellow liquid known as blood serum to separate. Such shrinkage exhibited by fibrin and other colloidal gels is known as svineresis (p. 118)

The relation between whole blood and serum is as follows Whole blood minus the formed elements is plasma, plasma minus fibringen is serum

Circulating blood contains platelets, yet coagulation does not occur in the blood vessels. With the knowledge that blood contains prothrombin, calcium ions, and fibrinogen, the question might be rightfully asked why the blood does not ordinarily clot in the blood vessels. This is due to antiprothrombin which mactivates the prothrombin. When blood exudes from the body, the platelets rapidly disintegrate and there is present a substance which neutralizes the antiprothrombin, with the result that the prothrombin, found only in the presence of vitamin K (p 599), is free to act and a blood clot is formed. Strong evidence has been adduced to show this substance is thromboplastin, or a closely related substance liberated from the damaged tissues or blood platelets. The thromboplastin counteracts an antiprothrombin, heparin, which prevents the change of prothrombin into thrombin.

Summarizing this theory (Howell's) of the normal clotting of the blood may be schematically represented as follows

-> Thromboplastin \*\*\* Heparin Complex + Prothrombin

The prevention of the clotting of shed blood may be brought about by the removal of the calcium ions (Ca<sup>++</sup>), one of the essen tial factors in coagulation. The usual laboratory anticoagulants

are ammonium oxalate and sodium citrate. In collecting blood for transfusions citrate is used since it is nontoxic and can readily be metabolized by the recipient whereas oxalate is relatively toxic when administered intravenously Commercial anticoagulants are hirudin, an extract from leeches, and heparin, an extract from liver or lungs. When freshly drawn blood is whipped, the fibrin collects on the apparatus used, leaving a suspension known as de fibrinated blood, which will not clot Usually the clotting time of blood is about three minutes but there are cases of people whose blood is very slow in clotting These people are called hemophiliacs (bleeders) This condition is hereditary and transmitted only through the female but manifests itself only in the male progeny Extensive investigations have been made in an effort to determine the nature of the clotting defect in hemophilia but at the present time the cause is not apparent. It may be due to a lack of thrombo plastic factors

Not infrequently, blood clots called *thrombi* occur in blood vessels, the clotting being due mainly to damage of the endothelial linung of the blood vessels. Such clots may cause serious disorders and even death

### SELF-TESTING QUESTIONS

- 6 What is the chief function of each formed element ?
- 7 How are the corpuscles separated from the plasma and identified?
- 8 Why are repeated blood transfusions necessary in some pathological conditions?
- 9 Describe the mechanism by which oxygen and carbon dioxide are carried in the blood
- 10 Name three conditions producing anemia
- 11 What produces hemolytic changes in the red cells?
- 12 How do leukocytes differ from erythrocytes?
- 13 How do the white cells function?
- 14 What is pus largely composed of?
- 15 What is the main function of the platelets?
- 16 What is syneresis?
- 17 What is the explanation for the fact that blood does not ordinarily clot in blood vessels?
- 18 Prevention of the clotting of blood to be used for chinical purposes depends upon what?
- 19 What is used to prevent blood clotting during collection of blood for transfusions?
- 20 What are thromb; and how may they be formed?

### III. ACID BASE BALANCE OF THE BLOOD

### Constancy of Blood Reaction:

It has been shown how certain salts in the blood assist in maintaining a constant normal alkaline reaction by counteracting the influence of varying quantities of acids and bases derived from foods However, no explanation has been previously given as to how the proteins also function in this respect Before considering the action of the proteins, it is advisable to turn to page 186 and review the data given on this regulating system of the blood whereby it can take up tremendous amounts of acids and some bases without any appreciable change in its normal alkalinity The maintenance of this constant reaction depends mostly upon the amount of available basic bicarbonate (NaHCO3). the basic and acid phosphates, and the proteins. The functional action of the lungs in eliminating carbonic acid, and that of the kidneys in excreting ammonium salts, or positive ions (Na. K. Ca. Mg) and amons (Cl. HCO3, HPO4, H2PO4, etc.) are also of great assistance in maintaining this acid base balance

# Hydrogen Ion Concentration, pH

Since the acid base balance of the blood and the hydrogen ion concentration of other solutions are frequently described in terms of pH, it is necessary before proceeding with the study of the blood to refer to page 163 for a general discussion of the significance of this term. For those interested, the accompanying note gives a brief mathematical explanation

In solution any acid, HA, will dissociate into a varying amount of ions.

HA # H+ + A-

the concentration of the H+ ions determining the strength of the acid

A base BOH will likewise ionize to a varying degree in solution,

BOH # B+ + OH-

the strength of the base depending upon the concentration of the OH- ions

When water dissociates

HOH # H+ + OH~

the concentration of the ions is slight In water, or any aqueous solution, the concentrations of these ions are mathematically related as follows:

The  $K_{\infty}$  is a constant and by calculation is  $10^{-14}$  at ordinary temperature Obviously an increase of the H+ causes a decrease in OH-, and vice versa. Since a water molecule yields one H+ and one OH-, the concentration for either becomes  $10^{-7}$ , which means that one liter of H<sub>2</sub>O contains 1/10,000,000 or  $1\times10^{-7}$  grams ions of H+. One gram ion of H+ then is in every 10,000,000 liters of water. In blood there are 3.98/100,000,000 or  $3.98\times10^{-8}$  gram ions of H+ per liter. To express very small hydrogen ion concentrations without the use of decimals, Sorensen introduced the

symbol pH for logarithm  $\frac{1}{H^+}$  Then in the case of blood,

$$pH = log \frac{1}{3.98 \times 10^{-8}} = log \frac{10^8}{3.98} = 7.4$$

the pH value is the negative logarithm of the hydrogen ion con centration of the solution, expressed in gram ions for each liter

It should be pointed out again that as the pH increases the hydrogen ion concentration decreases, and, furthermore, that a change of one pH unit means a tenfold change in the hydrogen ion concentration. Thus pH 10 is ten times as acid as pH 20 or 100 times as acid as pH 30. Neutrality is pH 70 at 20°

ρΉ	Hydrogen Ion Concentration in Gram ions per Liter			
14	10-14	t		
13	10-13	جأدو		
12	10 12	Increasing		
11	10-11	퇴급		
10	10-10	임니肖		
9	10-9	#   <b>*</b>		
8 7	10 8	1		
7	10 <sup>-7</sup>	Neutral		
6	10-0			
5	10-5			
4	10 4	Increasing		
3	10 <sup>-3</sup>	8 9		
2	10 <sup>2</sup>	Acidity		
1	10-1	417		
0 ]	10° = 1	i		

### Profess as Buffers.

With the understanding that proteins contain basic groups, —NH<sub>2</sub>, and acid carboxyl groups, —COOH, we can understand how the blood proteins, including hemoglobin (Hb) and oxyhemo globin (HbO<sub>2</sub>), can act as buffer substances in regulating the acid base balance by preventing changes in hydrogen ion concentration when small amounts of acids or bases are added. In the case of the proteins there are three possible ratios

HHbO2 (free oxyhemoglobin)
BHbO2 (alkali salt of
oxyhemoglobin)

HHb (free or acid hemoglobin)
BHb (basic hemoglobin salt)

H protein (free protein)

B protein (alkali proteinate)

The action of protein in neutralizing an acid is as follows

HA + B Protein -> H Protein + BA
(strong (alkali (free or acid (solt)
acid) protein protein (solt)

Whereas the strong acid dissociates to give large numbers of hydrogen ions, the acid protein dissociates but slightly to give relatively few hydrogen ions

### SELF-TESTING QUESTIONS

- 21 What are buffers?
- 22 Using the carbonate or phosphate buffer mixture explain how the blood remains normal upon the addition of acids and bases resulting from metabolic changes
- 23 Why can proteins act as buffers?
- 24 What two kinds of acting substances make up all buffer pairs? (p 187)

From the discussion on pages 185 to 187 and herein, it is evident that there are five lines of defense to resist change in the hydrogen ion concentration, and of these the buffer effect proper of bicar bonate in the blood is relatively unimportant compared with that of the hemoglobin

### IV. BLOOD CHEMISTRY

# **Tests for Blood**

Quite frequently occasions arise when there is a demand for knowing whether a stain is blood, and if so whether it is himan blood. Of the chemical tests to determine the presence of blood, the hemin test is very satisfactory. The technic involves boiling the stain in question with glacial acetic acid and sodium chloride, cooling and making microscopic examination for crystals of hemin or hematin chloride. Another test for blood which is very sensitive and is used for the detection of blood in biological material such as urine, feces and gastric juice is the benzidine test. In this test a solution of benzidine in glacial acetic acid is mixed with hydrogen peroxide and the material suspected of containing blood. In the presence of blood an intense blue color develops. Dilutions of blood as great as 1 to 500 000 can be identified by this method

It is only within recent years that a method has been developed to make an absolute differentiation of human blood. This is a biological test based upon the fact that the blood serum of any animal which was previously injected only with human blood produces a precipitate only with human blood. Such a test is good for stains that have dried even for months and will show positive results in dultinons as high as 1 to 50,000.

# Blood Groups and Transfusion

For a long time, it has been known that the blood serum of some people will agglutinate (clump) or hemolyze blood cells of other people, and that this is the main cause of severe reactions that may follow blood transfusions. Investigation has shown that the red cells of a given individual may contain either one or both of two agglutinable substances A and B, and that the serum from a given individual may contain either or both of two isoagglutinins or antibodies, anti A and anti B The reactions of different cells and sera show the presence of four blood groups, namely O, A, B, and AB Thus there are four types of cells as follows 1 Those that contain agglutinogen substance A, 2 Those that contain agglutin ogen substance B, 3 Those that contain both A and B, and 4 Those that contain neither agglutinogen substance A or B Cor respondingly the serum may contain antibodies or isoagglutinogens in four combinations 1 An antibody for A. 2 An antibody for B. 3 Antibodies for both A and B, and 4 No antibodies for either A or B

Since, in addition to the nomenclature by letters, the numberings are still in use, their relationship is presented as follows

Nomenclature by Landsteiner	Jansky	Moss
0	I	IV
A	11	II
В	111	111
AB	IV	I
	}	

In blood typing the problem is to find the type of the donor's blood and the type of the recipient's blood. After a donor of the proper type is obtained for a recipient, a compatability test is usually carried out in which donor's and recipient's blood are mixed. The discovery of the blood groups in man has cleared up many untoward effects observed prior to this knowledge.

The table on page 455 shows the types of reactions

Notice that no agglutination takes place when the blood cells of the donor and the serum of the recipient belong to the same group

# The Rh Factor in Blood

In addition to the four major blood groupings—types A, B, AB and O, which make safe transfusions possible, there also are other factors or agglutinable substances (antigens) for which ordinarily no corresponding isoagglutinins (antibodies) are found in human sera. It is these antigens which, without corresponding antibodies, may present medical problems in human transfusions.

Prior to World War II it was known that the blood of a mother could cause the death of her own baby even though both parents belonged to the same blood group In 1940 it was discovered that the blood of the rhesus monkey injected into a rabbit produced an antibody (agglutnin) in the serum, which clumped not only the red cells of the monkey, but also the red cells of about 85 per cent of white people notwithstanding their major blood group This agelutnable substance is celled the Rh factor

This agglutinable substance is called the Rn facto

Rhesus mankey
or Rh+ blood (injected into) rabbit = antibody formation

This rabbit serum

/agglutination in 85% (Rh+)

mixed with human blood =

no agglutination in 15% (Rh-)

# METHOD OF TESTING BLOOD GROUPS

Recipient— Serum of Group			Donor-Red Blood Cells of Group				Remarks pertaining to the vertical
Inter- national	Jan- sky	Moss	0	A	В	AB	columns O, A, B, AB
0	I	ıv	0	(*;*)		(	Cells of Group O not agglutinated by any sera Contain no ag- glutinable substances Universal Donors (45 per cent of adults)
A	п	п	0	0	0	(3)	Cells of Group A ag- glutinated by sera of Groups O and B (40 per cent of adults)
В	ш	111	0		0	0	Cells of Group B ag- glutinated by sera of Groups O and A (ten per cent of adults)
АВ	IV	I	0	0	0	0	Cells of Group AB agglutinated by sera of Groups O, A, B Serum of Group AB contains no isoagglutinns Universal recipient (5 per cent of adults)

When recipient is group O, select donor from group O

" " " A, " " " " Oor.

" " " B, " " " Oot B
" " " AB, " " " O, A, B, AB

If possible use donors of the same group and not universal donors Why is group O called the universal donor, and group AB a universal recipient?

The 85 per cent are termed Rh positive (Rh+), and the remaining 15 per cent are Rh- (Fig 4).

And here is where the trouble starts

When Rh+blood gets into the blood stream of an Rh-person the tissues combat Rh+by making antibodies (agglutinins) which



Fig. 3—Testing for Rh. The small vial (left) contains enough serum to make hundreds of tests to find out whether blood is Rh positive. After the blood to be tested has been diluted with salt solution, it is put in the tube with the anti Rh serum (notif). Courtery Science Service.

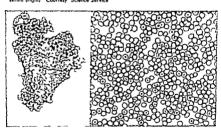


Fig 4—Final Blood Examination. After Incubation and centrifriguing, the blood is examined under a microscope if the cells have clumped together (left), then the blood is pos tive Ith blood. If the cells show distribution after the blood is put in the tube with the onli Ith serum, then the blood is Rh negative (right). Courtery, Science Service.

in repeated transfusions destroy Rh+ red cells, and the patient becomes violently ill and may die, primarily as a result of kidney damage by the destroyed red blood cells (Fig. 4)

In pregnancy when the mother is Rh — and her baby Rh+ (inherited from Rh+ father), blood from the unborn travels into the mother's blood stream to produce antibodies, some of which return to the child and destroy blood cells Miscarriage, stillborn, death soon after birth, erythroblastosis (a hemolytic disease), and in some instances feeblemindedness may occur. No harm results how ever, if an Rh — mother has an Rh — child. In modern hospitals stocks of Rh — blood from professional blood donors are kept ready to administer to a newborn beby. The plasma is always safe since it contains no red cells and hence no Rh factors.

From this brief discussion it is evident that blood should be typed for Rh factor as well as for the major blood group types. It is important to avoid giving an Rh - recipient Rh + blood and is also important in anticipating problems arising from an Rh - mother having an Rh + baby.

### Collection and Preservation of Blood

In a physiological sense the blood must reflect the condition of every tissue and any disease or change involving the fixed tissues of the body. Studies have shown that in some instances these changes are so characteristic of certain diseases that they may be regarded as constant signs and often the most important part of the clinical picture, and diagnosis is impossible without a knowledge of them. Knowledge of these blood changes, therefore, is necessary for diagnosis, prognosis, and treatment of many of the internal diseases encountered by practicing physicians. In some, the blood changes alone are sufficiently characteristic to establish the diagnosis, but more often they are only suggestive, and must be interpreted in the light of all additional clinical evidence that may be obtained

Compared to a few years ago, when blood tests were quite difficult, we now find that some blood tests are simple, rapid and accurate enough to be carried out in the physician's office

In hospital work, chemical blood analyses are now made so frequently and in such large numbers that the nurse must know how to take and preserve blood specimens

If possible, the blood should be collected in the morning, before any food or liquid has been taken. The blood is more uniform at this time and permits an analysis to be made on the same day instead of standing over night and undergoing some changes.

If the blood is immediately refrigerated, it may be kept for a few hours but the sooner the test is made the more satisfactory are the results. The nurse may be asked to assume responsibility for immediate delivery of the sample to the laboratory 458 Biochemistry

The amount of blood required for chemical studies may vary from a fraction of a milliliter which can be collected from a finger tip or ear lobe to 10 to 20 ml of blood which is collected from a vein If a glass syringe is used the blood should immediately be dis charged into a one ounce bottle which contains two drops of a 20 per cent solution of potassium oxalate, this latter substance acting as an anticoagulant. The contents of the bottle should be mixed (not shaken) with a rotary motion to allow mixing with the oxalate solution.



Fig 5—CO<sub>2</sub>. Comb hing Power of Blood. Carbon dioxide it carried from the issues and to the lungs the fig. in comb act on with fixed bases which are important buffer substances in the blood. When the clikal reserve is a minished the carbon dioxide carrying capacity of blood is correspondingly decreased. The picture below shows the van Syke method of determining the carbon dioxide combining power of blood. When the clikal reserve is decreased beyond a cartain point what cond to many be said to be present? Courtey Parks Our s.

When the blood is to be employed for acid base balance studies i. e., pH and CO<sub>2</sub> determination) (Fig. 5) it should be drawn with minimal stasis. This may be done with or without the use of a tourniquet. However, when the needle has entered the vein, and a tourniquet has been used, it should be released and a minute's time should elapse before blood is drawn. Furthermore, the blood must be drawn and preserved under mineral oil, which protects the specimen from the CO<sub>2</sub> of the atmosphere. When extreme accuracy is not of vital importance, CO<sub>2</sub> determinations may be made on blood which was not protected by a layer of mineral oil, if the analysis is promptly carried out.

# Blood Analysis as an Aid in Diagnosis and Prognosis:

In addition to the importance of being able to take and preserve blood specimens, a nurse should be able to interpret the figures resulting from laboratory tests. For instance, N. P. N. 50 should have a meaning and give some indication of a patient's condition. With that in mind the table on page 460 is inserted to show the range of changes usually encountered in several common metabolic disorders.

Notice the numbers indicating the normal and the pathological change, and also the significance attached to abnormal amounts of the different blood constituents.

Of particular interest and importance in the table are the readings in nephritis. Normally the kidney eliminates the nonprotein nitrogen (N. P. N.) waste products (urea, uric acid, and creatinine), and is impenetrable to colloidal materials (proteins); but when damaged the permeability changes, and the extent of the retention of the waste products is often an index of the severity and progress of the disease. Such readings are a helpful guide to the physician.

Another disease of not uncommon occurrence is diabetes, believed to be occasioned by damage to pancreatic cells, which fail to secrete sufficient insulin for proper metabolism of sugar. Notice the low and high readings for sugar (40 to 1300) and the low and high readings for carbon dioxide capacity (5 to 130), the low reading indicating a reduction of base forming materials (the alkaline reserve of the blood) that is always associated with acidosis (acctone, acetoacetic and beta hydroxybutyric acids). When the acids use up the alkaline reserve (alkali available to combine with CO<sub>2</sub> and other acids) the blood cannot combine with as much carbon dioxide as formerly. Consequently, the determination of the amount of carbon dioxide that can combine with the blood shows how much

# CLINICALLY SIGNIFICANT BLOOD CONSTITUENTS\*

Blood Constituents Tested for per 100 ml of Blood	Normal Range (Units per 100 ml of Blood or Serum)	Begin ning Patho logic Ranget	Patho logic Range	Significance
Hemoglobin	14-17 Gm	-12	3-23	Low in anemia
Total plasma protein	60-80 Gm	~60	30-60	High in polycythemia Low in nephrosis, low in protein deficiency
Plasma albumın	36-56 Gm	-35	10-36	Low in nephrosis, low in protein deficiency
Plasma globulm	13-32 Gm	~13	04-13	Low in nephrosis, low in protein deficiency
Nonprotein nitro gen (N P N) Urea nitrogen Creatinne Uric acid Blood sugar CO <sub>2</sub> capacity Cholesterol Serum calcium as calcium Serum inorganic phosphorus as phosphorus Adult	25-35 mg 12-15 mg 1-2 mg 1-3 5 mg 70-120 mg 50-70% by volume 140-170 mg 9 11 mg	+35 +20 +35 +4 +150 -45 -130 +170 -8	20-400 5-350 to 34 to 27 40-1300 5-130 60-1000 3-20	High in nephritis High in nephritis High in nephritis High in ephritis High in ephritis, gout High in diabetes Low in nephritis, aci dosis high in alkalosis High in nephritis low in anemia Low in tetany, stages of nephritis high in hyperparathyroidism Low in rickets High in stages of nephritis
Children Chlorides as NaCl Plasma Whole blood	4-6 mg 570-620 mg 450-520 mg	-4 -500 -450	300-850 120-700	High in nephritis with edema, nephritis, eclampsia, low in pneumonia
Icterus index (terms of 1 10 000 potas sium dichromate)	4-6	+10	10-225	High in hemolytic ane- mia, hepatic jaundice, and obstructive jaun dice Indicates liver disturbances

<sup>•</sup> Myers V C J A M A vol 91 † Below is indicated by a (一) sign and above by a (十) sign.

of the alkaline reserve has been used up in neutralizing these acids and it will represent the extent of acidosis

Normally, the blood contains about 0 1 per cent (70 to 120 mg per 100 ml) of blood sugar, which may increase to about 0 2 per cent before the kidneys become permeable and allow it to pass into the urine. In diabetes the concentration runs even higher. The blood sugar test is valuable not only in diagnosing diabetes and in treating the disease after glucose or insulin injections but also in determining the blood sugar tolerance in endocrine (thyroid and nituitary gland) disturbances.

Finally, one more disease will have to be mentioned among those in which blood analysis aids diagnosis, a disease called anemia, in which the hemoglobin is considerably lower than normal content of 14 to 17 Gm of hemoglobin per 100 ml of blood. This may be the result of a reduced number of red cells or a reduced amount of hemoglobin in the cells which may result from hemorrhage or in fectious diseases such as diphtheria and syphils. With a low hemoglobin content, the oxygen carrying capacity of the cells is so small that partial tissue asphyxia may result. Diets for anemia patients must be nutritious and contain sufficient iron and protein for the production of hemoglobin. Recent experiments indicate that copper in foods in some way—probably as a catalyst—stimulates the utilization of iron in the formation of hemoglobin.

From the preceding brief discussion, it is evident that blood analysis gives first hand information concerning many diseases, and in many cases more definite information than urnalysis. In the case of diabetes in particular, a blood sugar analysis may indicate the presence of the disease long before such an indication could be found by analysis for sugar in the urne

As a remaining statement, blood analysis has also given helpful information in diagnosis and prognosis of such diseases as gout, nephrosis, mercury poisoning, urologic conditions, eclampsia in testinal obstruction alkalosis, certain malignant conditions tetany and nickets

#### SELF-TESTING QUESTIONS

- 25 What is a test for blood?
- 26 How can human blood be differentiated from other bloods?
- 27 What is the basis of blood grouping?
- 28 What is meant by the Rh factor?
- 29 Abnormal amounts of what substances in the blood indicate kidney disturbances?
- 30 What does a high N P N indicate?

- 31 In diabetes what blood constituents would have a high or low reading?
- 32 Why is the blood sugar test important?
- 33 What kind of blood determination is used in anemia?

# V. PLASMA

## Function of Plasma

The plasma, a faint yellowish liquid, makes up slightly over one half of the volume of whole blood, and contains solid matter dis solved or in colloidal condition. It is this colloidal nature of plasma which makes it viscous and somewhat translucent. The approximate composition of plasma is shown in the table below.

Plasma usually is regarded merely as a vehicle for transportation of erythrocytes. Obviously, its frue significance is not always recognized. What the erythrocyte is to gaseous (O<sub>2</sub>, OO<sub>2</sub>) metabolism, the plasma is to nitrogen, mineral, and water metabolism. The plasma supplies the fuel, and the erythrocytes supply the oxygen needed for internal combustion. In a sense, the plasma itself constitutes a liquid fuel. It distributes food glucose, amino acids and lipids it is the medium for chemical reactions, it transports en zymes, hormones and specific products of cells to their allotted

	Water	91%		
Plasma			Proteins (serum albumin serum	
(ap gr 1 025)	)		globulin and fibrinogen)	70%
	Solid	9%	Salts (morganic)	10%
			Fat sugar and other organic	
		1	substances	10%

seat of action, it removes and conducts waste products to the organs of excretion, it carries the materials necessary for repair, it auto matically and immediately seals riptured walls of the blood ves sels, and it regulates heat The plasma, therefore is a marvelous internal medium which in health is continuously replemshed and purified, and yet is maintained at a remarkably constant volume and composition

### Function of the Plasma Proteins

Of the solid matter in the plasma, the larger part is protein, namely, serum albumin, serum globulin, and fibringen Together with the lipids (fat like substances), these proteins form the structure of the plasma

The fact that blood contains a great amount of water (78 per cent) and therefore is more fluid than other tissues is due primarily

to the characteristic property of the colloids (proteins) in absorbing and holding the water in the form of gel. As has been mentioned (p. 186) and is more fully discussed on page 452, the proteins, as well as certain salts, act as buffers in regulating the normal reaction of the blood

As an additional function, the plasma proteins assist in the elimination of waste products in the cells. There are other functions of the plasma proteins, the most important of which is to maintain normal osmotic pressure between the blood and tissues. In the state of shock, when plasma proteins leave the vascular bed, the blood is left in a concentrated condition. Administration of albumin or blood plasma is valuable in reheving this condition. Furthermore, we must not forget the special function of soluble fibringen in changing into insoluble fibrin to form the blood clot (p. 447).

## Other Plasma Constituents

The small amount of morganic salts present in the plasma are mostly sodium chloride and bicarbonate. In still smaller amounts are found potassium, calcium, and magnesium salts. Reference (p. 188) has already been made to their chief physiological uses, their special properties, and their importance in health and life

The fats and lipids, lecithin and cholesterol are studied under the various functions of the blood

### SELF-TESTING QUESTIONS

- 34 What is the main function performed by the plasma?
- 35 What other functions are attributed to the plasma?
- 36 What is the role of the plasma proteins?
- 37 The plasma proteins give what properties to the blood?

### VI. FUNCTIONS OF THE BLOOD

# Transportation of Nutrients and Oxygen:

As stated, one important function of blood is to transport nutrients in solution from the intestines and storage depots, and oxygen
in combination with the hemoglobun of the red cells from the lungs
to the tissues. As a result of the digestion of general foodstuffs
containing carbohydrates, fats, and proteins, we find glucose,
resynthesized fats, amino acids, inorganic salts, vitamins, and
water in the blood. These materials, along with the oxygen from
the lungs, are carried by the blood to the cells where they may be
used either as fuel for the conversion of chemical energy to me

chancal or heat energy, or to build tissue Although during absorption of these nutrients, the concentration is greater, still to does not increase very much, because of rapid use or storage by the tissues. This is especially true in the case of high protein consumption, for very little accumulation of amino acids occurs in the blood. The ingestion of large quantities of sweets may run the sugar content of the blood from 0.09 to 0.2 per cent but utilization by the tissues and the conversion into glycogen by the liver and muscles soon reduces it to normal. In case glucose does accumulate in the blood at a faster rate than it can be used or stored by the tissues the threshold point of the kidneys is reached and sugar will be excreted into the unne—a nonpathological condition referred to as almentary glycosura. The quantity of fats and fatty acids in the blood may increase for a short time following fat ingestion to an even greater extent than glucose, occasionally imparting a milky appearance to the blood

The water and inorganic salts are absorbed rapidly from the intestines, but excessive dilution of the blood and an abnormal change in the osmotic pressure is prevented by elimination of water and salts through the kidneys

In certain diseased states it may be desirable to supply nutrients directly to the blood by intravenous administration. It is also desirable in some conditions to supply needed salts or electrolytes. The table on the following page shows some of the more commonly used intravenous solutions.

### Transportation of Waste Products

The second important function of the blood is to transport waste products of metabolism from the tissue cells to the organs of excretion (kidneys, lungs, intestines, skin and liver which eliminates waste products in the bile). The following table shows the important waste products handled by the excretory organs

### EXCRETORY ORGANS AND THEIR WASTE PRODUCTS

Kidneys	Lungs	Intestines	Skin	Luer
Water	Water	Water	Water	Water
Salts		Salta	Salts	Salta
N Compounds		N Compounds		N Compounds
Pigments etc	Carbon dioxide	Pigments etc Food residues		Pigments etc

### REPRESENTATIVE SOLUTIONS FOR PARENTERAL USE

Preparation	Vehicle	Also Known As	
Salıne (NaCl) 09%	Distilled Water	Physiological Saline Normal " Isotonic "	
Ringer's 0 86% NaCl 0 03% KCl 0 033% CaCl <sub>2</sub>	Distilled Water		
Invert Sugar 10%	Distilled Water	Travert®*	
Dextrose 5 % to 20 %	Distilled Water	Glucose 5% to 20%	
Amino Acids, Peptides and Polypeptides	5% Dextrose, distilled water or saline		
Darrow's Solution 0 27% KCl 0 30% NaCl 0 60% Na lactate	Distilled Water		
Potassium Chloride 0 3%	10% Invert Sugar		
Lactate Ringer's 0 60% NaCl 0 03% KCl 0 02% CaCl <sub>2</sub> 0 31% Na lactate	Distilled Water	Hartmann's	
Alcohol 5%	09% Saline 50% Dextrose		

Whole blood and plasma are also commonly used, as well as the commercially obtainable plasma,—albumin and globulin \*Emeans registered name

The morganic salts include the bicarbonates, chlorides, phosphates, and sulfates The mitrogenous substances usually referred to as the nonprotein nitrogen (N. P N) are creatmine, urea, uric acid, and ammonium compounds

Since all absorbed foods (glucose, fats, amino acids) contain carbon, hydrogen and oxygen, the two main products of oxidation are carbon dioxide and water. In the case of amino acids we have 466 Biochemistry

certain introgenous substances (mostly urea) also formed, while if sulfur and phosphorus are present they are oxidized to the corresponding sulfates and phosphates. The chlorides undergo no change. The carbon dioxide as has previously been stated unites with water, with the alkali or proteins present, or dissolves in the blood, and is carried to the organs of exerction.

# Transportation of Hormones.

A third important function of the blood is to transport for distribution and utilization secretions, or hormones, of certain glands (endocrine) These glands are often referred to as the ductless glands since their secretion is poured directly into the blood. Hormones stimulate certain tissues, and in this way harmonize the activities of organs located in different parts of the body

For instance, the blood carries from the ovarian gland a secretion which affects the development of sex characteristics of various parts of the body In a few instances, however, glands may have both an external secretion and an internal secretion. An example of such a case is the pancreas in which the pancreatic juice is the external secretion and insulin is the internal secretion, insulin being the hormone which has an important role in carbohydrate metabolism. Although the amount of secretion is very small, its influence on metabolism is very great.

### Diffusion of Heat.

This is a fourth function of the blood. In exidation of foods and of devitalized tissue, or as a result of other metabolic changes in the body, energy is liberated. During rapid oxidation of glycogen or fat in the more active tissues, such as muscles, the blood quickly moderates this localized higher temperature by distributing the heat through the circulating blood to the surface of the body where it is lost by conduction and radiation. Then the blood vessels are dilated, and the skin becomes flushed Water can store more heat than the same volume of any other substance and as a consequence the water of the blood absorbs heat, and upon evaporation from the sweat glands and mucous surfaces, assists in regulating body temperature Exposure to cold causes a contraction of the blood vessels and diminishes the cooling area of the surface blood vessels with the consequence that relatively little blood reaches the surface of the body to lose heat At such times, the skin may appear pale and numbness may even result

# Defensive Action of the Blood

A fifth important function of the blood is to aid in defending the body against invading disease organisms, a function performed by the white cells and the antibodies. This function has already been discussed (p 446)

## Other Blood Constituents

There are many remaining substances in the blood, but space does not permit a discussion of them There are, however, two lipids, lectifun and cholesterol, that deserve mention These are primary cell constituents that supposedly have some relation to the transportation of fat to the tissues, and the intermediary metabolism of fats Their determination is of diagnostic value in certain pathological conditions (diabetes, nephritis, anemia, etc). The blood also contains certain enzymes such as amylase and phosphatase. The measurement of blood amylase concentration is quite useful in the diagnosis of acute pancreatitis since in this condition it is markedly elevated. Phosphatase concentration is creased in certain bone disorders. There are also present antien zymes, which can inhibit enzyme action, and antibodies which can combine with and counteract the effect of toxins elaborated by bacteria.

### Tissue Oxidation

This is a fascinating but rather difficult field of biochemical study Recent experiments in vivo and in vitro have thrown much light on the subject but it is rapidly changing. A few general statements must suffice in this course

The oxidase enzymes present in tissues bring about certain types of contation in the presence of certain organic intermediates. There is another mechanism which is known as "dehydrogenation" or loss of hydrogen, which really amounts to oxidation of the substance which loses the hydrogen. An interesting example of this type of reaction is that of glutathone. It has been synthesized and concrete facts about its action are now well known. It is an excellent example of an organic "hydrogen acceptor," that is, it accepts hydrogen from the substance being ordized and thus becomes reduced itself. It later becomes oxidized again, and functions over and over again as a "hydrogen acceptor," thus favoring tissue oxidations.

#### SELF-TESTING QUESTIONS

- 38 What are the most important nutrients carried by the blood?
- What nutrients are present in increased amounts in the blood following the ingestion of large quantities of food?

40 What is meant by alimentary glycosuria?

- 41 What are two main waste products of metabolism?
- 42 What happens to most of the nitrogenous foods?
  43 What salts are most likely to occur in the excrets?
- 44 What is a hormone?

cells under normal conditions

- 45 Explain how the blood helps to equalize body temperature
- 46 How does the blood defend the body against disease?
  47 What is one function of lecithin? of cholesterol?
- 48 How does oxidese seems in tissue oxidetion?

# VII EXTRACELLULAR WATER AND LYMPH Functions of Lymph

Since the blood in its circulation to all tissues of the body is in a closed system of blood vessels, a more intimate communication with the individual cells is brought about by another haud, namely the extracellular body water, a colorless watery fluid surrounding each cell It is derived from the blood and the tissues by a passive ultrafiltration process, and so closely resembles blood plasma that it is often thought of as "blood without the red corpuscles or protem" It is via the extracellular water that the cells obtain their food and discharge their waste material. The extracellular body water therefore may be considered as the 'middle man" or "go between" for blood and tissues Not only is it the means by which food materials of the blood diffuse into the cells of all tissues, but it is also the medium through which the products of chemical activity in each cell gain access to the blood. There is a continuous exchange of materials going on between the cells and the blood plasma via the extracellular water. Its composition closely resembles that of the plasma, and whenever fluctuations in the con centrations of the constituents take place, the diffusible substances

Lymph and extracellular water have an almost identical composition. When extracellular water enters the small blind ended vessels known as the lymphatics it is then usually called lymph. These vessels are distributed among practically all of the body cells. They units to form larger vessels which eventually pour their contents into the blood stream chiefly through the thoracic

pass with ease and rapidity between the blood and the tissue

duct This is one of the large lymph vessels. It is the general trunk of the whole lymphatic system, draining the smaller lymphatics from the legs, abdominal organs and left side of the body. It is about 20 inches long and empties into a large vein of the neck on the left side, at the junction of the subclavian and internal jugular veins. Under normal conditions there is a continuous movement of water from the capillary blood vessels to the extracellular spaces and in turn into the lymphatics It is in this way that most of the iymph is returned to the blood again. The advantage of the po-sition of the extracellular water between body cells and blood is that it makes the exchange of materials between blood and body cells easier In addition, the lymph, in its circulation through the body, filters through lymph nodes or glands, and in this way it can collect, remove, and destroy much foreign material such as infecting bacteria, which may have entered the tissues This destruction of bacteria often prevents the spread of infection to different parts of the body

# VIII. ANTIBIOTICS AND SULFA DRUGS

The antibotics are organic substances of complex character which are usually produced by microorganisms and are used to combat certain pathogenic bacteria. In this category of anti bacterials penicillin, streptomycin, Aureomycin and Chloromycetin are outstanding

Pencillin, of which there are several types, has been more thoroughly studied than others, it is produced by the fungus or mold called Penicillin notatum which is grown commercially on a large scale in a liquid culture medium Penicillin G is quite effective, and in the form of the calcium or sodium salt it is given by intra venous or intramuscular injection, or by surface application in the treatment of numerous infections

Streptomycin, a product of a soil microorganism, is produced today in considerable quantity from cultures. As an antibiotic streptomycin is effective against certain pathogenic microorganisms which are impervious to penicillin, and it is used in treating such infections as tuberculosis, tularemia, typhoid fever and wound infections.

Chloromycetin is of interest masmuch as it is the first antibiotic to be successfully synthesized artificially. Like streptomycin, this antibiotic is produced in nature by a soil microorganism. Chloromycetin has proven effective in treatment of virus pneumonia.

The study of antibiotics is today one of the very active fields of biochemical research, and it is quite probable that other useful substances of a similar nature will be found

The sulfonamude or "sulfa" drugs are synthetic chemicals which have proven valuable in treating various bacterial infections. The sulfonamides are derivatives of sulfanilamide, (p. 321) and all have in common the following unit of structure.

Of the many compounds of this type that have been synthesized, four are sufficiently important to warrant mention

Sulfamlamde results when a hydrogen atom is attached to the free bond of the above structure Sulfapyridine, sulfathnazole and sulfaduazine are formed by attaching a pyridine, thiazole or diazine nucleus respectively to the free bond of the structure pictured. The derivatives of sulfamlamide are less toxic and more effective than sulfamlamide itself. These drugs have value in treating pneumonia, infections of the blood stream, streptococci infections, etc. In some individuals serious reactions develop from the use of sulfa drugs, hence they should never be employed without the direction of a physician

### SELE-TESTING OUESTIONS

- 49 How does extracellular water differ from blood?
- 50 What is the main function of the lymph?
- 51 What are the advantages of having a separate lymphatic system between the cells and the closed system of blood vessels?

### SUGGESTED ACTIVITIES

- I THOUGHT PROVOKING QUESTIONS
  - 1 Why is there a need for a circulatory system?
  - 2 How does the blood in the right auricle (atrium) differ from that in the pulmonary vein?
  - 3 Compare and contrast in tabular form the crythrocytes the leukocytes and the platelets with regard to their structure function, and site of formation

- 4 What dietary precautions should be observed in nephritis in diabetes and in anemia?
- 5 Why could the body not exist without lymph?
- 6 During colds and other infections the lymph nodes frequently swell Why is this?
- 7 Under what circumstances might it be desirable to know whether a given sample of blood is human blood?
- 8 Does the formation of pus in a wound always indicate an infection?
- 9 Under what varying conditions are blood transfusions necessary?
- 10 Is it ever desirable to let blood out of the body as the early surgeons used to do either by bleeding the patient or by using leeches?
- II Why is hemophilia a dangerous disease? What treatment is used? II PROJECTS

III

- Read some additional material on the chemical analysis of blood Study the hospital charts of patients with diabetes and nephritis with special regard to the blood chemical studies
- 2 Make a list of the various fluids in the body and show in tabular form the composition and chief functions of each

VOCABULARY TESTI	ng of New Terms		
plethora	anemia	fibran	hormone
plasma	leukemia	syneresis	antienzyme
erythrocytes	prothrombin	hemophilia	antibody
leukocytes	thromboplastin	thrombi	lymph
platelets	heparın	isoagglutinins	serum
dehydrogenation	hydrogen acceptor	glycosuria	thrombin
polycythemia	fibrinogen		

#### IV TOPICS FOR ORAL OR WRITTEN REPORTS

- 1 Anticoagulants for Blood
- 2 Hemophilia
- 3 Biological Significance of Heme
- 4 Blood Banks and How They Are Maintained
- 5 Theories about Blood Clotting

#### LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on pages 741 744

#### CHAPTER XX

#### URINARY EXCRETION

# CHAPTER OUTLINE

- I. EXCRETION
  - (a) Anatomical and physiological
  - correlation (b) Excretion, products and
  - pathways (c) How the kidneys form urine
- II. EXAMINATION OF URINE
  - (a) Importance of unnalysis (b) Collection of urine for
    - analysis
- (c) Physical examination of urine volume, color, transparency, odor, specific gravity, reaction
- III COMPOSITION OF URINE
  - (a) Organic constituents (b) Inorganic salts
  - (c) Abnormal constituents
  - (d) Urmary calculi

### 1. EXCRETION

## Anatomical and Physiological Correlation:

It is assumed, that before coming to class, the students have reviewed the anatomy and functions of the kidneys, as it is not convenient to do so, except in a very general way, in this discussion. Indeed, the mastery of biochemistry will be greatly aided if a constant attempt is made to correlate other allied subjects with the chemical principles presented in this course. Frequent reference to illustrations in other texts will help one to understand difficult problems presented in the study of chemistry. The very background of biochemistry is the study of those chemical changes in organs (anatomy) and tissues (histology) which take place during active function in health (physiology) or in disease (pathology). Therefore, it is best to try to view the facts of biochemistry in relation to structure and function, rather than as an isolated subject.

## Excretion: Products and Pathways:

When food is ingested it undergoes a series of hydrolysis reactions and is eventually broken down to simple compounds that include monosaccharides, amino acids, fatty acids, and glycerol. These substances along with minerals and water are absorbed from the intestine into the blood stream and are thus made available for use by all body cells. In general, the cells carry out two types of reactions with these substances; they may be oxidized and broken down to carbon dioxide, water, and simple nitrogen compounds or they may be synthesized into complex substances. The first of the reactions is responsible for the conversion of chemical energy to heat energy and mechanical energy, whereas by synthesis new body

tissue is formed along with specific products which include hormones, enzymes, and a variety of other substances.

As a result of the chemical metabolic reactions, waste products are produced which must be excreted. These include water, carbon dioxide, urea, and other simple nitrogen compounds. In addition to these major waste products the body also has numerous other substances to be excreted which include: ingested water, substances absorbed from the food for which the body has no use, products arising from detoxification reactions, excess minerals, etc.

The pathways of excretion are the kidneys, the lungs, and to a lesser degree, the gastrointestinal tract, the liver and the skin. Most of the carbon dioxide excretion and a considerable portion of water excretion is carried out by the lungs whereas excretion of nitrogenous waste product is almost totally dependent on the kidney. We shall now consider the mechanism by which the kidney functions.

### How the Kidneys Form Urine:

The process by which the kidneys secrete urine is quite complex. Figure 1 is a diagram of the nephron which is the microscopic functional unit in the kidney. Each kidney contains approximately one million of these structures. The afferent vessel brings blood into the glomerulus which is a capillary network whose walls are semipermeable. These walls act as filters through which some of the water and crystalloidal components of the plasma pass into Bowman's capsule. Proteins, other colloids, and blood cells cannot pass through this filter and along with most of the plasma are carried out of the glomerulus by the efferent vessel. The process of filtration in the glomerulus is believed to be purely mechanical and is influenced by both blood pressure and osmotic pressure

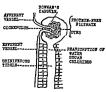


Fig 1—A Filtration Plant Diagram showing urine secretion. What is removed from the blood by the glomeruli? Courtery, Hawk and Bergeim, "Physiological Chemistry," P. Riokiston's Sons Co.

The amount of glomerular filtrate formed each day is approximately 100 liters or about 100 times as great as the volume of finally excreted urne. This filtrate then passes through the urniferous tubules which are long tortuous microscopic tubes lined with epithelial cells. In the tubule active reabsorption of water, glucose, amino acids, and salts occurs with little or no reabsorption of waster products. Those substances that are reabsorbed are spoken of as threshold substances whereas those that are not reabsorbed are called non threshold substances. This results in a very great concentration of the original dilute glomerular filtrate. The tubule cells also act in an excretory capacity and actually transfer certain material from the blood stream to the urne in the tubule. From the tubule the urne passes into larger collecting vessels and even tually leaves the kidney by the ureter and is stored in the bladder. In retrospect we see that there are three more or less independent phases to urne formation (1) glomerular filtration, (2) tubular reabsorption of water and useful constituents and (3) tubular excretion of additional waste products

It is both interesting and instructive to note at this time that while the amounts of uric acid, urea, ammonia, creatinine, phos phate and sultate are many times (25 to 100) as abundant in the urine as in the blood, the amount of chloride, sodium, calcium and magnesium remains roughly about the same, while in the case of glucose there is only a trace (about 0 05 per cent) in the urine and practically all of the sugar is reabsorbed

## SELF-TESTING QUESTIONS

- 1 What are five paths of excretion?
- 2 Explain the process by which the kidneys secrete urine
- 3 What substances are more abundant in the urine than in the blood?
  4 What compound is largely recovered after filtration through the plomerul?

# II. EXAMINATION OF URINE

# Importance of Urinalysis

Since the urine is the chief pathway for the elimination of waste products it is quite evident that the urine affords the physician or the nurse an interesting and helpful means of determining (1) whether normal metabolic changes are taking place, (2) whether abnormal waste products are being eliminated, and possibly some idea as to what may be the cause of these pathological changes, and (3) whether the kidneys are functioning close to outmum efficiency

# Collection of Urine for Analysis

Emphasis should be placed upon the importance of collecting the entire 24 hour output, because metabolic changes taking place in the body at various times of the day produce different concen trations of the constituents in urine. However, the first specimen is better for routine analysis. The quantity of water and food con sumed, and the amount of work done, in addition to many other factors (posture, stimulation, temperature, time of day, etc.) may cause wide variations in the composition of urine Except in specific cases, random sampling is less valuable and may be quite misleading in certain cases. As a consequence the usual hospital procedure is to discard the early morning (8 A M ) specimen of urine and collect all the urine passed during the next 24 hours This quantity includes that passed the following morning at 8 A M To minimize or inhibit bacterial action, the urine is perhaps most satisfactorily preserved with toluene and kept under refrigeration In case refrigeration is impossible, a thin layer of toluene over the surface of the urine is a quite satisfactory preservative that does not interfere with urmary tests. After measuring the total volume. a six ounce sample should be saved for analysis

## Physical Examination of Urine

The volume of urme secreted during a 24 hour period may vary considerably because of the influence of many factors, particularly the water intake. The average adult (except when excessive fluid intake occurs due to overconsumption of beverages or to polydipsia) excretes from 1000 to 1500 ml of urine in 24 hours. In some countries where beer makes up a large part of the fluid diet the output is greater. Of the normal factors influencing urmary volume two of the most important are the diet (fluids as water, milk, coffee, soups) and environmental temperature Vigorous exercise causes the sweat glands to secrete more perspiration and decreases the output of urme Less perspiration in cold weather accounts for the greater urine volume in the colder months. High protein diet and drugs (caffeine in coffee, in tea) also increase this excretion Drugs which increase the flow of urine are called diuretics Frequently, the kidneys become impaired (nephritis) and there is difficulty in eliminating the morganic and organic waste materials. At such times, the kidneys may excrete an increased volume of urine Night urine from a normal person is about one half of that formed during the day. The significance of various changes in volume in health and disease follows

Normal	Abnormal	Significance
1000 to 1500 ml (96 % H <sub>2</sub> O)		Depends upon water and fluid foods con sumed, exercise, temperature, kidney func- tion, nervousness, excitement, mental con dition, etc
	High (polyuria)	Diabetes mellifus, diabetes mapidus, nervous diseases, certain types of chronic ne phritis (kidney disorder), diureties (drugs as caffene, calomel, digitalis, alcohol, causing increased unnary excretion)
	Low (oliguria)	Acute nephritis, heart disease, fevers, eclampsia, diarrhea, vomiting
	None (anuria)	Uremia (unnary substances in the blood), acute nephritis metal poisoning, e g, due to bichloride of mercury

The color of normal urme is amber, the shade of yellow depending somewhat upon the concentration of the pigment urochrome and traces of other pigments. Very dilute urmes are almost colorless because of the large water content. Normally the amount of urmary pigments varies little from day to day—regardless of the diet. A variety of colors is obtained in pathological conditions as observed in the following table.

Normal	Abnormal	Significance
Yellow to amber		Depends upon concentration of pigment (urochrome)
	Pale	Diabetes insipidus, granular kidney, a very dilute wine
	Mılky	Fat globules pus corpuscles in genitouri nary infections
	Reddish	Blood pigments drugs food pigments
	Greenish	Bile pigment associated with jaundice
	Brown black	Poisoning (mercury, lead, phenol), hemor rhages, obstructive jaundice

A transparent and clear urine is normal when the sample is fresh, warm and of the proper dilution, but a precipitate of urates may appear on cooling and a precipitate of calcium phosphate may normally occur in an alkaline urine following a hearty meal Turbidity occurring on standing for several hours may be caused by the precipitation of mucin Variations in transparency and their significance follows.

Normal	Abnormal	Significance
Clear		No significance
Cloudy on standing		Precipitation of mucin from urinary tract Not pathological
Turbid		Precipitation of calcium phosphate Not pathological
	Milky (chyluria)	Presence of fat globules Pathological
	Turbid	Presence of pus as result of inflammation of the urinary tract Pathological

The odor of normal urine is faintly aromatic, probably due to certain volatile organic acids and an evil smelling substance called urinod. The odor of urines is also modified by the ingestion of certain drugs and vegetables. Asparagus, for example, imparts to urine a strong characteristic odor, caused by the presence of methyl mercaptan (CH<sub>3</sub>SH) Disbetic urine smells of acetone. The unpleasant ammonacal odor of old unpreserved urine is brought about by bacterial action (urease) which changes urea into ammonium carbonate, and then into ammonia

$$\begin{array}{c} \text{NH}_2 \\ \text{C} = \text{O} + 2 \, \text{H}_2 \text{O} & \xrightarrow{\text{Ureave}} & \text{C} = \text{O} & \longrightarrow & 2 \, \text{NH}_3 + \text{CO}_2 + \text{H}_2 \text{O} \\ \text{NH}_2 & & \text{ONH}_4 \\ \text{Urse} & & \text{Ammon wm} \\ & & \text{carbonate} \end{array}$$

The significance of various changes in odor follows

Normal	Abnormal	Significance
Faintly aromatic		No aignificance
	Pleasant (sweet)	Acetone, associated with diabetes mellitus
	Unpleasant	Decomposition, or ingestion of certain drugs or foods

The specific gravity of normal urine averages about 1 020, depending upon the concentration of solid matter. Normal urine sper may vary from 1 010 to 1 030 and may be even lower following a large intake of water. The more dilute a urine the nearer the specific gravity is prevalent when an unhealthy kidney finds difficulty in eliminating its salts, especially nitrogenous compounds. If the patient has acute nephritis, the urine is usually concentrated and the specific gravity is high, but if it is chronic nephritis then the kidney may excrete a greater volume of urine with a lower specific gravity. The specific gravity of the urine usually varient inversely as the volume, but in the case of diabetes mellitus this does not hold good, for then, both the specific gravity and the volume are high. The significance attached to an abnormal specific gravity follows.

	Normal	Abnormal	Significance
_	1 010 to 1 030 sp gr		Ordinarily, sp gr is inversely proportional to the volume
		Low	Dilution, if volume is large otherwise chronic nephritis, diabetes insipidus
		High	Concentrated if volume is small, otherwise if volume is large and light colored, dia betes mellitus Acute nephritis

It should be pointed out that the specific gravity of urine in disease is rarely outside of the limits that may be obtained in a healthy individual. However, the excretion of a very dilute or very 480 Biochemistry

concentrated urme by a healthy person can usually be associated with definitely altered intakes of fluid. Normally the kidneys can adjust specific gravity over the range from 1 000 to 1 030 depend ing on the relative amount of solid and water to be excreted kidney disease this power may be lost with the result that the kidney is not capable of adjusting the specific gravity which is spoken of as being "fixed" There are several clinical tests that are referred to as dilution concentration tests that are designed to determine this function of the kidney In general they may be carried out by having the patient ingest a large quantity of water and then not permitting any further water intake for 24 hours Urine samples are collected at regularly spaced intervals. The normal response to such a test is that for a short time after the large intake of fluid the urine has a specific gravity approaching that of water but by the end of the 24 hour period the specific gravity is over 1 030. In contrast, a patient with kidney disease may be unable to excrete either a very dilute or a very concen trated urine

A rapid clinical method of determining the specific gravity is the use of a unnometer. From the reading, a rough estimation of the total amount of solids per liter may be obtained by multiplying the numbers in the second and third place after the decimal point by 2.6 (Long's coefficient). For example. If the specific gravity is 1.021 the calculation would be

### 21 × 26 = 546 gm per liter of urine

The reaction of normal urine may be either acid or alkaline to litmus (pH 50 to 80) but is more frequently acid. This is caused mainly by the monosodium and potassium phosphates (e.g., NaH<sub>2</sub>PO<sub>4</sub>). The balance between the acid phosphate NaH<sub>2</sub>PO<sub>4</sub> and the basic phosphate Na<sub>2</sub>HPO<sub>4</sub> is one of many factors which influences the pH of urine, and makes the urine capable of be coming acid or alkaline to hitmus. The ratio between these two phosphates in both the blood and the glomerular filtrate is approximately the same, but in the urine there is a greater influence exerted by the acid phosphate, probably because of the selective excretion of the acid phosphate or the reabsorption of some of the basic phosphate. In this way the kidneys aid in regulating the neutrality of the blood.

The acidity of urine increases somewhat if the diet consists largely of acid forming foods (proteins) In certain diseases when the urine has a high acidity, a possible acidoas is suggested. This

of course can be confirmed or ruled out by blood chemical analysis On the other hand, an alkalme urine may result from a vegetable diet, as in the urine of herbivorous animals. Citrus fruits product an alkaline urine. It is interesting to note that the urine, after a heavy meal, may for some time remain neutral or even alkaline, which is known as the 'alkaline tide'. This is probably due to the increased demand during this time for acid radicals to form the hydrochloric acid of the restric unce.

The withdrawal of hydrogen ions from the blood tends to cause its reaction to become more alkaline. However, the excretion of an alkaline unne will enable the blood reaction to remain more or less constant. The urine may also become alkaline as the result of eating fruits and vegetables which are rich in alkaline minerals and are known as alkaline ash foods. Ingestion of sodium bicar bonate and other "alkalizers" will also cause the urine to be al kaline. The persistence of an alkaline reaction in the urine of a patient on a mixed due (e.g., aimmal and vegetable) points to probable infection of the bladder, providing that there has been no decomposition of the urine by putrefying bacteria. The significance of high acidity and an alkaline urine follows.

Normal	Abnormal	Significance
Acid (Slight)		Diet of acid forming foods (meats eggs prunes wheat etc) overbalancing the base-forming foods (vegetables and fruits)
	High acidity	Acidosis diabetes mellitus many pathologi cal disorders (fevers starvation)
	Alkalıne	Putrefying bacteria change urea into am monium carbonate. Urinary infection or ingestion of alkaline compounds.

From the foregoing, it is evident that the kidney in excreting either an acid or alkaline urine is a very important part of the body machinery in keeping the blood plasma slightly alkaline

#### SELF-TESTING QUESTIONS

- 5 In what four ways may urine analysis be considered important? 6 How should urine be collected and preserved for analysis?
- 7 Why is random sampling of urine generally of little value?
- 8 What are the two most important factors influencing urinary excretion?
- 9 Name several conditions producing polyuria oliguria, and anuria 10 What is the significance of a urine that is pale milky, reddish, greenish.
- or brown black? 11 Why are milky and turbid urines generally considered pathological?
- 12 What is the significance of pleasant and unpleasant odors in urine?
- 13 How does the volume of urme excreted usually compare with its specific
- gravity? Name an exception to the general rule 14 What compound causes an acid urine?
- 15 Explain how the kidney assists in regulating the neutrality of the blood
- 16 Why may human urine be acid or alkaline?
- 17 What probably produces the condition known as 'the alkaline tide'?
- 18 What is the significance of a highly said or alkaline urine?

## III. COMPOSITION OF URINE

The greater part of urine is water (96 per cent) in which are dissolved organic and inorganic waste products of the body. Of the organic matter, urea is the most important and abundant (approximately 50 per cent of solids), and is the principal nitrogenous end product of protein metabolism. Next to urea in abundance is the morganic constituent, sodium chloride, which makes up ap

Constituent	Gm
Water	1200 0
Solids	60 0
Organic	
Urea	30 0
Creatinine	1 2
Urië acid	07
Pigments etc	trace
Urochrome	1
Urobilin	1
Inorganic	1
Chlorides as NaCl	120
Sodium	40
Phosphates as P2O5	2.5
Sulfates as SO:	20
Potassium	j 20
Ammonis (in salts)	07
Calcium	02
Magnesium	0 15

proximately 20 per cent of the solid matter. Since diet and other factors have such a great influence on the composition of urine any urinalysis will show wide variations from time to time. See the representative analysis on the preceding page showing the most important constituents of urine.

## **Organic Constituents:**

Urea is the chief end product of protein metabolism (exogenous) or of tissue protein metabolism (endogenous), and it contains the greatest part of the nitrogen found in the urine. Urea is found in nearly all of the fluids of the body, and some experiments seem to show that organs and tissues other than the liver can form urea. However, practically all of the urea is formed by the liver. The kidneys remove urea from the blood and excrete it into the urine. A small amount is excreted in the perspiration and saliva. The output of urea varies with the amount of protein eaten; a high protein diet such as meat produces an increased amount of urea, This output might be expected to be large when it is remembered that the body requires only a limited amount of protein for tissue building, that proteins in the usual sense cannot be stored in the body, and that any excess of proteins is finally decomposed, yielding energy and fuel and nitrogen waste products. A low urea output is usually associated with a low protein diet or advanced kidnev disease.

Ammonia stands quantitatively next to urea as the most important nitrogenous constituent of protein metabolism (Fig. 2).



Fig. 2—Ammonium Urate. Spherule and thorn crystals. Metallic urates may occur in the sediment of acid urines. Name them. Courtery, Hawk and Bergeim, "Physiological Chemistry," P. Bickiston's Sons Co.

The ammonia usually occurs as ammonium chloride, phosphate, or sulfate. The ammonia odor sometimes noticed in old urine is the result of fermentative bacteria changing urea to the unstable compound ammonium carbonate (p. 478). The importance of ammonia in abnormal metabolic changes is often attached to its use in neutralizing acids formed in excess of the amount which could be completely eliminated. For instance, in diabetes mellitus there is an increased amount of ammonium salts in the urine. This is the result of the urea acting as a source of an alkali capable of neutralizing certain organic acids (e. g., acetoacetic and beta hydroxybutyric acids). Under these circumstances the following reactions occur:

- a.  $(NH_2)_2CO + 2H_2O \rightarrow (NH_4)_2CO_3$
- b. (NH<sub>4</sub>)<sub>2</sub>CO<sub>3</sub> + H<sub>2</sub>CO<sub>3</sub> → 2NH<sub>4</sub>HCO<sub>3</sub>
   c. 2NH<sub>4</sub>HCO<sub>3</sub> + 2NgCl → 2NH<sub>4</sub>Cl + 2NgHCO<sub>3</sub>

From the equations the following facts can be indicated: (1) The bicarbonate formed in reaction c is available for neutralization of acid. (2) In the series of reactions producing bicarbonate, urea is used up and ammonium chloride is formed. This means that there are more ammonium salts and less urea to be excreted. Thus the ratio of urinary urea to urinary ammonium salts can be used as an indication of whether or not acidosis exists. (3) The reactions are in part responsible for the body's margin of safety in production against acidosis. (4) If alkalosis rather than acidosis is existent, then the reactions do not take place and practically no ammonium salts are excreted in the urine.



Fig. 3—Creatinine Colorless crenatine crystals. Of what value is a creatinine determination? Courtesy, Hawk and Bergeim, "Physiological Chemistry," P. Blakiston's Sons Co

In addition to the formation of ammonia from urea (p. 478), it must not be overlooked that copious water drinking and acid forming foods (proteins) also increase the ammonia excretion, while on the other hand base forming foods (fruits and vegetables) decrease the amount of ammonia excreted

Creatine and its anhydride creatinine are both normal organic con stituents of tissues, the former being especially abundant in muscletissue. Creatinine, but not creatine, is a product found in the normal urine of adults (Fig. 3). Creatine is found only in the urine in children, in pregnant or menstruating women, and in such pathological conditions as fasting, fevers, diabetes, and diseases involving a condition of acidosis.

Although creatumne metabolism is not clearly understood, it is definitely known that creatimne is a product of creatine issue metabolism (endogenous creatinue), and is related to the amount of muscle tissue in the body. The daily output of creatinine excreted remains so constant that the determined amount in a 24 hour sample serves to check this quantitative collection. An abnormal amount in the blood points to nephritis and uremia. In decided contrast to the quantity of urea, the amount of creatimne in the urine is independent of the protein ingested.

Uric acid represents a fairly small, but important, organic con stituent of normal urine. Usually uric acid occurs in the form of salts called urates, and since these salts are insoluble in concentrated urines, they readily separate to form the largest part of the sediment of urine. Uric acid, unlike urea, does not come from ordinary protein metabolism, but from the destruction of nucleoproteins of foods or tissues. It may be recalled that the nucleo proteins are conjugated proteins formed by the reaction of nucleoproteins are conjugated proteins formed by the reaction of nucleoproteins are conjugated proteins formed by the reaction of nucleoproteins are conjugated proteins formed by the reaction of nucleoproteins are conjugated proteins formed by the reaction of nucleoproteins are conjugated proteins formed by the reaction of nucleoproteins are conjugated proteins formed by the reaction of nucleoproteins and such containing glandular organs (liver, kidneys, and sweetbreads) which are rich in cell nuclei, and also asparagus, spinach, and legumes will markedly increase the output of uric acid. Foods such as fruits, milk, eggs, and carbohydrates, however, give an almost purine or nuclein free diect, with the result that very little uric acid is formed. This is of decided value in the treatment of certain diseases (e.g., gout) caused by the inability of the kidneys to eliminate uric acid properly. Being relatively insoluble (1 to 15,000), uric acid is excreted with difficulty. When there is some abnormal condition in uric

acid metabolism the amount of unc acid in the urine is decreased, while in the blood it is increased. At such times, the unc acid is deposited in the joints or affected tissues in the form of crystalline urates. To activate the kidneys and increase the unc acid output, such drugs as the salicylates, aspinn, and cinchophen have met with very doubtful success. Careful regulation of a purine free diet, plenty of dirinking water, and exercise are perhaps of some assistance in the elimination of unc acid.

Sometimes there is too much destruction of nucleoproteins and a corresponding increase in the unc acid excreted. This would be true in malignant diseases resisting treatment (cancerous growths) in which the cells are destroyed, and also in leukemia where the leukcoytes (white cells) are produced and destroyed in greater numbers.

The fact that unc acid has slight reducing properties makes Fehling's test for sugar in urine unreliable However, unc acid will not reduce Nylander's reagent (bismuth submitrate) or Benedict's solution, which reagents will show the test for sugar

Pigments normally occurring in urine include urochrome, urobilin, and uroerythrin Urochrome, the principal pigment, is a constant product of endogenous metabolsm, but it is increased in fasting, in fevers, in hyperthyroidism and acid administration, and it is decreased during alkali administration Urobilin is derived from the bile, and becomes of diagnostic value only when there is an increase due to liver disease Uroerythrin imparts the pink to red color found in normal urine. It increases in various pathological conditions (fevers, liver disorders) directive dischipances)

## Inorganic Salts

The morgame or mineral constituents found in the urine are largely the chlorides, sulfates, or phosphates of sodium, potassium, calcium, and magnesium. Since they are the end products of food and tissue metabolism, or are obtained directly from the morgame salts in the foods, the amount of these materials depends largely upon the variety and quantity of foods consumed. As stated, pro tem foods produce acid radicals, while vegetables, fruits, and milk tend to produce the basic ions.

Chlorides are next to urea in abundance of solid material in the urine. The principal chloride is sodium chloride, the excretion of which depends upon the chloride content of the food and the water consumed. In fasting, the percentage of salt in the urine runs low,

but it stays normal in the blood. A decrease in urmary chlorides is associated pathologically with the formation of exudates,  $e \ g$ , in neumonia, fevers and conditions involving edema

Sulfates are mostly derived from the oxidation of certain proteins containing sulfur. In pathological conditions involving acute fevers, and during stimulated metabolism, the excretion of sulfates is increased, while a decrease is noted in disease involving a loss of appetite and lowered metabolism.

Phosphates are obtained from the morganic phosphates in foods, and also from the oxidation of phosphorus organic compounds. The phosphates of the urine consist of Na<sub>2</sub>HPO<sub>4</sub>, and NaH<sub>2</sub>PO<sub>4</sub>, the latter salt accounting for the slight acid action of urine. As previously stated, these two salts act as buffers in maintaining the normal reactions of the body. An increase in the excretion of phosphate is connected with disease of bones (rickets, osteomalacia), pulmonary tuberculosis, diseases involving a decomposition of nervous tissue, and with water drinking, while a decrease is observed in pregnancy during fetal bone formation, in kidney diseases, in acute infectious diseases, and in febrile affections

Sodium and potassium are always present in urine because of the sodium chloride and the potassium salts present in foods. Potas sium chloride cannot be substituted for sodium chloride in the blood. The ratio of Na to K in urine is nearly five to three. An increase in potassium has been noted in conditions of acidosis and in fevers.

Calcium and magnesium are excreted principally in the feces and to a lesser extent in the urine. An excess of urinary calcium is associated with certain bone diseases (osteomalacia), while a low calcium content is prevalent in rickets. Since some magnesium is retained in osteomalacia while calcium is being lost, it is evident that the excretion of these two elements does not run parallel.

### Abnormal Constituents

In pathological conditions, abnormal constituents are found in the urine, the most frequent of which are proteins, glucose, acetone bodies, bile, blood, and bus

Proteins being of a colloidal size are not capable of filtering through the kidney and consequently when found in the urine usually indicate nephritis This permeable condition of the kidney permits protein to pass into the urine and results in a condition called renal or true proteinuma (or albuminuma) to distinguish it

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from accidental albuminuma, in which latter condition the protein does not come from the blood, but is the result of injured cells of the urinary tract below the kidneys. In some diseases of the urinary tract, blood proteins and pus will respond to the usual protein tests (Heller's, Esbach's) Although protein in the urine indicated sisturbances of the kidneys, it should be considered only in connection with other climical findings. The samplest test for protein is the formation of a precipitate when urine is heated with a few drops of acetic acid, the acid dissolving any precipitated phosphates

Actione appears along with acetoacetic and  $\beta$  hydroxybutyric acids (acetone bodies) When found in the urine (a condition called acetonize or ketonized) it is the result of incomplete oxidation of fatty acids. Such a condition may be seen in healthy individuals when fasting, or with a high fat and a low carbohydrate diet, but it most often appears in diabetes mellitus and during high fevers. In very severe forms of diabetes, the alkaline reserve of the blood is so depleted by these acids that a fatal acidosis may develop. Since ammonia is a reserve supply of alkali (formed at the expense of the urea), a considerable part of the acids formed are found in the urine as ammonium salts of these acids, and since acetoacetic acid readily changes into acetone, the usual tests are made for acetone. Rothera's test for acetone and acetoacetic acid occurs on p. 754

Glucose in more than mere traces in the urine is considered natho logical and this condition is known as glycosuria (sugar in the urine) However, glucose may be excreted in the urine because of a low renal threshold, giving rise to so called renal glycosuria One type called temporary glycosuria is the result of the ingestion of more sugar than the body can store at one time, the average glu cose tolerance being around 50 Gm per dose without producing glycosuria Temporary glycosuria may occur during vigorous exer cise, or strong emotions such as worry, or excitement, which latter condition may possibly be due to oversecretion of epinephrine by the suprarenal or adrenal glands The other type called permanent glycosuria (diahetes mellitus where there may be as much as 10 per cent of sugar found in the urine) is not caused by a disease of the kidneys but rather by a lack of insulin or the mability of the body to store and burn glucose properly, with the result that sugar retained in the blood stream is very high and large amounts are excreted in the unne As has been previously stated, one test (Benedict's, p 329) for glucose is based upon its ability to reduce

metallic hydroxides in an alkaline solution, and may be distinguished from lactose by the fact that lactose does not undergo fermentation with baker's yeast.\*

Lactose has been found in the urine during pregnancy and lactation, but does not apparently have any pathological significance.

Bile pigments produce a yellowish green to brown color in urine which upon shaking readily produces a foam of a yellowish cast. Pathologically, the excessive production of bile or obstruction to its excretion into the intestine gives rise to jaundice. The bile then stains various tissues of the body. The tests for bile depend upon oxidation of the pigments to form various colors (green, blue, yellow) appearing as rings at the point where the reagents meet in the test tube.

Blood may occur in the urine (hematuria) because of a lesion in either the kidney or in the urinary tract below the kidney. Also when hemolysis of the blood corpuscles takes place (laking of cryth rocytes) the blood pigment passes into the urine (hemoglobinuria). This latter condition may occur in scurvy, malaria, in severe burns, in some types of poisoning, in transfusing blood that undergoes hemolysis in the patient's blood, and in other pathological conditions. The most delicate test for blood is a blue color produced by the benzidine test (see laboratory experiment, p. 754).

Indican in excess is indicative of excessive intestinal putrefaction, and is the result of detoxication of indoxyl which results from putrefactive changes of the amino acid tryptophan. Obermayer's test for indican occurs on p. 755.

Pus usually develops in inflammatory conditions, such as catarrh of the bladder, inflammation of the pelvis of the kidney, and inflammation of the urethra, or in abscesses of the urnary tract. Pus in the urine is known as pyuria. In a broad sense, a pus cell is a dead leukcoyte. Pus cells may be detected under the microscope; they appear as round, colorless, nucleated cells.

Sedment: A microscopic examination of the sedment of pathological specimens is quite helpful in diagnosis and prognosis. Although the sediment may be collected by allowing the urine to stand for many hours, it is much quicker and more satisfactory to remove the sediment by centrifuring the urine. Perhaps the most

<sup>\*</sup>There are at the present time several commercial preparations available for the detection of super in the inner The most inside seed of these is "Clinited" which is based on the copier reducing properties of glucose in het alkaline solutions. In this test a small tablet, containing copier and table and a nutriture to generate best when the tablet discovers, if dropped into a small quantity of times and in the presence of glucose the mixture takes on a normer color due to reduced conner.

important elements in the sediment decompose on standing, so that unless the specimen is centrifuged much of the diagnostic value of the examination is lost. The sediment will fall under two classes first, the unorganized, containing calcium phosphate, unc acid and the urates, and the second, the organized, containing the epithelial cells, pus cells, cylindroids, and casts. An occasional red cell may be present but an increased number indicates a pathological condition.

Unorganized	Organized
Calcium phosphate Uric acid Urates, etc Sulfonamide crystals in patients receiving the drug	Epithelial cells Pus cells cylindroids Casts etc

Normal urine upon standing generally produces unorganized sediment, which dissolves upon warming, diluting, and adding a few drops of dilute hydrochloric acid, provided that only phosphates or urates are present. Uric acid sediment is soluble in sodium hydroxide. In the presence of organized sediment, heat will probably coagulate the protein Moreover, hydrochloric acid may precipitate the protein and destroy the casts, while sodium hydroxide not only dissolves mucous cells with the formation of a clear solution but also makes the pus gather into a thick, sticky mass. In addition, treatment with sodium hydroxide also destroys any microorganisms present as evidenced by the production of a milky appearing urine which cannot be clarified by filtration.

An increased number of epithelial and pus cells is frequently present in specimens from females (who have leukorrhea), other wiss they indicate some disturbance along the unnary tract, although a small number may not be pathological. Much pus indicates bacterial infection as in venereal diseases and renal abscesses Sometimes the kidney tubules become packed with protein and other material to form a cylindrical mass. Upon being discharged the mass retains the shape of the tubules to form what are called casts, and indicate some kidney disturbance, whether albumin is present or not. The expelled protein mass may tear loose some kidney cells and produce hemorrhage.

## **Urinary Calculi:**

Sometimes the mineral salts precipitate in such large and compact masses in the urinary tract to form stones, called calculi, although the process is a gradual one. An examination of these stones shows that mineral constituents mostly have been deposited in concentric layers on a nucleus of epithelial debris, a blood clot, or more likely uric acid or urate crystals. Generally, the calculi are voided without any difficulty before they have become very large, but when lodged in the pelvis of the kidney, or in the duct (ureter) that carries the urine from the kidney to the bladder or in the bladder, they may be very large, sometimes weighing from



Fig. 4—Casts. Cylindrical molds of uriniferous tubules forced out by the pressure of the urine flow. h, hyaline cast, g, granular cast, w, waxy cast, e, epithelial cast. What does the finding of casts indicate?

1 to 50 Gm. or even more. The color, form, hardness, and composition of the calculi vary greatly, according to the diet and the acid condition of the urine as well as the cause. Calculi are more apt to form when there is: (1) A highly concentrated urine, and (2) an abnormal amount of uric acid eliminated, (3) genitourinary infection, (4) a shortage of protective colloid (such as hyaluronic acid) in the dispersion of urinary crystalloids.

Chronic vitamin A deficiency in rats is associated with degenerative changes in the kidneys and calculus formation. In fact, experimentally, this is the most effective way of producing stones in the urinary tract. It is believed that infection sets in, producing stassis and decomposition of the urine, making it alkaline and precipitating salts which form calculi.

<sup>\*</sup> Stass is the arrest of the blood current due, presumably, to abnormal resistance of the capillary walls

#### SELF-TESTING QUESTIONS

- 19 What is the significance of a low urea output?
- 20 How is ammonia formed and what is its importance in the urine?
- 21 What is a guide to the severity of acidosis?
- 22 What significance is attached to the presence of creatinine?
- 23 What foods increase and what foods decrease uric acid formation?
  24 Explain how uric acid in the form of urates produces usin in the joints
- in such a disease as gout
  25. How may use acid elimination be increased?
- 26 What are three important urine pigments?
- 27 What is the significance of decreased chlorides? of increased sulfates? of decreased and increased phosphates? of increased potassium? of decreased and increased calcium in the urine?
- 28 How would you distinguish between renal and accidental proteinuria?
  29 In what metabolic disturbances is nectore produced?
- 30 What is the distinction between temporary and permanent glycosuris?
- 31 What is the distinction between temporary and permanent glycosuria?
  31 What is the significance of bile, blood pus casts and calculum the urine?

## SUGGESTED ACTIVITIES

- I THOUGHT PROVOKING QUESTIONS
  - 1 What happens to the health of a patient when carbohydrates are withdrawn from the diet?
    - 2 How should the diet of diabetics differ from that of nephritics? Give reasons for your answer
    - 3 If a diabetic on entering the hospital has acidosis how may you account for the condition? What measures should be taken to relieve it?
  - 4 If the elimination of nitrogen in waste materials of the urine exceeds the intake of nitrogen in the proteins of the diet, what conclusions would you draw? How could this condition be remedied?
  - 5 What happens in the tissues when the intake of food exceeds the needs of the body? When it is insufficient? By what means may we determine these facts?
  - 6 What are the disadvantages of eating an excessive amount of protein? The advantages if any
  - 7 Name several circumstances under which the need for mineral matter is greater than usual. Describe the results when this need is not supplied
  - 8 In what respect does the metabolism of a diabetic differ from that of normal persons? Describe how this modifies his use of food and how the d et should be modified.
  - 9 Discuss the advantages and disadvantages of milk as a food for infant feeding
  - 10 Following the discovery of sugar in the urine what other condition should be present before diagnosing diabetes?

- 11 How are the composition and properties of urine modified by the following
  - (a) Exercise?
    - (b) High protein diet?
    - (c) Acute nephritis?
      - (d) Chronic nephritis? (e) Diabetes?

(i) Bone diseases?

following urinalyses?

- (f) Vegetable diet, fruit, nuts milk? (g) Injection of baking soda?
  - (h) Starvation?
- (i) Eating glandular organs (liver, kidneys sweetbreads)?

- (k) Injury to cells of urmary tract? (I) High fat and low carbo
  - hydrate diet? (m) High fevers, diabetes?
  - (n) Eating ½ lb of candy?
  - (o) Jaundice?
  - (p) Lesions in kidney or uri nary tract?
  - (q) Inflammatory conditions? (r) Infection of the urmary tract?
- 12 What condition would most likely be indicated by each of the

Volume	Color	Sp Gr	Sugar	Protein	Acetone	Acid	Alkalıne	Casts	Pus	Bile	Sediment	Blood	Indican in Excess
Large		_	+	_	_		_	_		_		_	
Large			=	+					_				_
Small				+	_		_	<del> </del> +	J	_	,	TT.	
Small	Dark Yellow										+ on standing clears on beating		
			+		E	High	_		=				
											clears on acid ifying		
		l—				<u> </u>	+		+			<u>+</u>	-
	Gr Br Yellow Foam			1	ļ	1	ļ			+	]		+
	roam		<u> </u>			1 _	<u>L</u>			L	<u></u>		

## II VOCABULARY TESTING OF NEW TERMS

polyuria urochrome oliguria urmometer anuna "alkaline tide" chyluria albumunuria proteinuria ketonuma

acetonnus. hemoglobinuria casta urmary calculi

DYUMA

III TOPICS FOR ORAL OR WRITTEN REPORTS

- Value of Urmalysis in Diagnosis 2 The Organs of Excretion What They Accomplish
- 3 How the Kidneys Function in Urine Formation

## LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on pages 749, 752

#### CHAPTER XXI

#### CHEMICAL CHANGES IN THE TISSUES

#### CHAPTER OUTLINE

- I METABOLISM
  - (a) Chemical nature of metabolism
  - (b) Energy metabolism
- II BASAL METABOLISM (a) Determination of basal
  - metabolism (b) Internal factors affecting basal
  - metabolic rate (c) Variation in weight
  - (d) Variation in height
  - (e) Variation in age (f) Variation in sex
  - (g) Variation of internal secretions
  - (h) Specific dynamic action of foods (i) Practical value of ascertaining
- the metabolic rate III METABOLISM OF CARBOHYDRATES
  - (a) The high energy bond
    - (b) Changes produced by the liver (c) Anserobic catabolism
    - glycolyms (d) Theserobic phase trientboxylic
    - acid cycle (e) Conversion of glucose to fat
  - (f) Carbohydrate tolerance
- IV METABOLISM OF FATS (a) Function of fats

- (b) Oxidation of fats (c) Incomplete fat metabolism
  - (d) Ketosis and antiketosis
- V METABOLISM OF PROTEINS.
- (a) Function of ammo acids (b) Oxidative deamination
  - (c) Transammation
  - (d) Urea formation (e) Nitrogen balance
- VI METABOLISM OF INORGANIC SALTS (a) Classification of inorganic (ash) elements
  - (b) General functions of morganic
  - (c) Control of contraction of mus cles and irritability of nerves
  - (d) Maintenance of osmotic pressure
  - (e) Role in acidity and alkalimity of digestive juices (f) Preservation of normal chem ical reactions
- VII METABOLISM OF WATER
  - (a) Adaptation of life to water (b) Water exchange

  - (c) Water needs

## I. METAROLISM

### Chemical Nature of Metabolism:

There are many different manifestations of life exhibited by the cells, involving a correspondingly large number of chemical changes which are always accompanied by energy changes. The general expression used for the sum of all these energy changes is metabolism. which in a restricted sense is defined as the rate of the oxidation processes

The word "metabolism" involves two phases of chemical reac tions, the building up process called anabolism and the tearing down process, called catabolism Anabolism, or constructive metabolism, refers to the building up of body tissues and reserve nutrients stored in the body Catabolism, or destructive metabolism, refers to the breaking down of discarded body cells and waste products. The anabolic and catabolic processes during normal adult life usually balance each other, the constructive processes equalling the destructive ones. In youth or during a convalescent period, anabolic functions may be greater, while in old age, disease, violent exercise, and malnutrition, catabolism is more preponderant.

Cells vary markedly in their specific functions, even though all cells have access to the same supply of food carried by the blood The selective power of each cell is such that it takes only what it may assimilate, rejects what may not be used, and this selective power represents one of the mysteries of life. There are differences in concentrations of various substances between the inside and outside of the cell. Of the many substances taken into the cell. oxygen is of utmost importance, since it is a vital factor in almost all metabolic changes The use of oxygen in the body makes possible the production of energy of which the greater part (four fifths) appears as heat It is interesting to note that Lavoisier was the first to study the role of oxygen in generating heat and potential energy of the body. He made a chemical study of the respiration of living forms, finding that the life of an animal, like a candle's flame was dependent upon the continual removal of oxygen from the atmosphere, and upon the return of an equivalent quantity of carbon dioxide He found, moreover, that the amount of oxygen consumed was related to the amount of heat developed by the Life, declared Lavoisier, is a chemical process akin to combustion This was an epoch making discovery

### Energy Metabolism

The carbohydrates, fats, and proteins can be used equally well to supply fuel for heat and mechanical energy. The proteins are unique, however, in that they alone are capable of restoring or building new body tissue. This is readily understandable when we recall that most functional body tissue is of a protein nature and that proteins contain mitrogen whereas fats and carbohydrates do not.

Energy is expressed in terms of units of heat. The amount of heat required to raise the temperature of 1 Gm of water 1° C is called a calorie. However, to measure the energy changes of the body it is more convenient to select a heat unit 1000 times as large called the large Calorie (capital C) or kilocalorie, which is the amount of heat required to raise the temperature of 1000 Gm

(1 kg) of water 1° C The caloric value of a food is determined by placing a weighed quantity in a bomb calorimeter (Fig. 1), filling the bomb with oxygen under pressure, closing, and immersing the bomb in a weighed quantity of water. The food is then ignited by an electric current, and the rise in temperature of the water is measured. By means of this instrument the physiological fuel values of foods show that

- 1 Gm of carbohydrates produces 4 1 Calories
- 1 Gm of fats produces 9 1 Calones
- 1 Gm of proteins produces 4 1 Calories

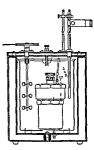


Fig 1 — Food Values Determined with a Calo rimeter The cross section of the colormeter shows the colormeter bomb immersed in water in which is a stirrer and thermometer. Why is the heat obtoined in the colormeter slightly higher than that shown for the oxidation of a food in the body?

For convenience these values usually are used as whole numbers as follows carbohydrates, 4 Cal  $/\rm{Gm}$  , fats, 9 Cal  $/\rm{Gm}$  , and proteins 4 Cal  $/\rm{Gm}$ 

From these values the calonc value of any food may be est mated  $\,$  For instance, in the following example 100 Gm  $\,$  of milk furnishes 68 Calones

Food	Per Cent Analysis		Calories per Gram		Total Calories
Carbohydrate	5	×	4		20
Fat	4	×	9	-	36
Protein	3	×	4	=	12

Various proportions of the three principal foodstuffs for daily requirements have been suggested, a favored one being that of the German physiologist, Voit He proposed 500 Gm of carbohydrates, 56 Gm of fat, and 118 Gm. of protein. Such a diet would furnish approximately 3000 Calories, an amount sufficient for a normal adult engaged in ordinary activities. The exact protein requirement has been seriously debated by many investigators. The current views appear to indicate that 60 to 90 grams of any



Fig 2—Gwng a Basal Metabolism Test. The amount of oxygen consumed is used in calcifulating how much food in being oxidized or the number of colones of energy produced. This amount of energy (basal metabolism) is compared with a charl, showing the overage normal metabolis create for a person of the same height, weight, age, and sex. What do you think would be the practical value of accertancing the metabolic rate? Courtery, Saham Campany.

good protein per day is quite adequate for a healthy adult Recently it has been shown that in many diseases an increased intake of protein is quite beneficial

### SELF-TESTING QUESTIONS

- 1 What is meant by metabolism? Anabolism? Catabolism?
- 2 How is the caloric value of a food determined?
- 3 What are the physiological fuel values of carbohydrates fats and proteins?

## II. BASAL METABOLISM

## Determination of Basal Metabolism

The consumption of food as well as the activity of the body varies It follows that the energy demand made on the body (or the cells composing it) must also vary from time to time. The harder the physical work, the greater the amount of heat produced by the body. At complete mental and physical rest and in the absence of food in the stomach and intestines, certain basic energy changes in the cells are still going on, otherwise there would be no life, but these energy changes are at a minimum. At such times, the body may be likened to an idling automobile—ready to perform work at a moment's notice. This minimum amount of energy required to maintain life when the body is at rest, at normal tempera ture, and when no digestion is going on is known as the basal metabolic rate. (B M R.)

Under such conditions the energy requirement, measured as the amount of heat evolved in large Calories per 24 hours per sq meter of body area, called the basal metabolic rate, is a gauge of the speed at which metabolic processes are taking place. To produce this energy transformation without ingested foodstuffs means that chemical reactions are taking place on the food stored in the body, chiefly fats and carbohydrates Since there is a definite relation between energy production and oxygen consumption the usual clinical method of obtaining the basal metabolic rate is to determine the amount of oxygen consumed by a patient (who has been properly prepared) during a period of six to eight minutes (Fig 3) The average oxygen consumption per minute is then estimated From this the 24 hour oxygen requirement is easily calculated The amount of oxygen consumed is used in calculating how much food is being oxidized, or the number of Calories of energy produced This amount of energy, the basal metabolic

rate, is compared with a chart showing the average normal basal metabolic rate for a person of the same height weight, age and sex Any variations from the normal are reported as percentage variations plus or minus —10 meaning 10 per cent below the normal, +10 meaning 10 per cent above normal The normal basal metabolism of an adult male of average size and about thirty five years of age is 39 5 Calones per square meter per hour For a body area of 18 square meters this represents a basal metabolism of approximately 1700 Calones per day The basal metabolic rate of a normal person before breakfast is so constant that a variation from normal of more than 15 per cent is indicative of some disturbance in the vital processes

These facts are fundamental in dietetics, for they mean that an adult confined to bed would need 1700 Calories even if he never turned over a lifted a hand



Fig 3—The Bened ct Roth Metabolism Apparatus. Note in the illustration how the apparatus also makes a graphic chart record of the patient's oxygen con sumpt on. Courtesy Warren E Call ns Inc

## Internal Factors Affecting the Basal Metabolic Rate:

There are many factors that must be considered in carrying out a basal metabolic determination. Such external factors as exercise, eating or fasting can be controlled in making a basal metabolic test but not such inherent factors as weight, height, age, sex, and internal secretions. All must be taken into account in estimating the significance and the value of the basal metabolic rate (B.M.R.).

## Variation in Weight:

In two men of the same height, one distinctly thin and one fat, it has been found that a smaller amount of heat will radiate from the thin man. For this reason consideration must be given to the surface area of the body.

## Variation in Height:

The same reasoning shows that two men of the same weight, but differing in height, will have different amounts of heat radiation, height increasing the heat radiation.

## Variation in Age:

Of considerable interest is the effect of age on the basal metabolic rate, the production of heat being greater in youth than in old age. During physical growth increased height and weight may sometimes counterbalance a difference in age. For instance, a youth of 12 years of age might have the same production of energy as one 16 years old. The latter's increased height and weight may at times counterbalance a decreased energy production.

### Variation in Sex:

Another interesting fact is that for some reason (probably more fat and less muscle in the female) the basal metabolic rate of women is about 10 per cent lower than that of men of the same height, weight, and age. This is so because B.M.R. measures "active" protoplasm, and fat is not very active tissue.

## Variation of Internal Secretions:

The internal secretions, or hormones, of certain glands (endocrine) stimulate body tissues, and in this way markedly influence the basal metabolic rate. For instance, the adrenal glands may affect blood pressure, the pituitary glands influence growth, the Islands of Langerhans control sugar metabolism, and the secretion

of the thyroid gland increases the rate of oxidation. Feeding thy roid tissue or thyroid extract to any animal (including man) always raises the B M R. When the thyroid gland produces more secretion than is required by the normal body, a disease known as hyperthy roids m develops and the basal metabolic rate must always be above normal in this disease.

Recent work on animals has shown that certain fractions of the pituitary gland have a profound influence on the basal metabolic rate. A potent extract may produce a marked increase in B M R

### Specific Dynamic Action of Foods

Ingested foods speed up oxidative reactions in the tissues to produce energy I nother words foods stimulate the rate of metabolism, the effect being referred to as the specific dynamic action of food. Of the different foods proteins have by far the greater and more prolonged specific dynamic effect. To maintain the oxidative reactions in the tissues, that is, to supply the energy required to metabolize foods, it has been estimated that on an average mixed diet over 10 per cent of the total food Calories used must be added to the basal requirement in order to take care of this specific dynamic effect. Therefore, a daily energy requirement embodies the basal energy requirement, the energy for muscular activity, and the energy for the specific dynamic action during metabolism.

### Practical Value of Ascertaining the Metabolic Rate

Since under normal conditions the metabolism remains fairly constant from day to day, any marked variation will be of definite clinical assistance in diagnosing certain pathological states. This is especially true in the diagnosis and prognosis of goiter. In fact, several metabolic disturbances are associated with over or under secretion of the thyroid gland. A lack of this secretion (hypothyroidism) may result in a gain in weight, apathy, muscular weak ness perspiration, and flushing of the skin, while an excess secretion (hyporthyroidism) produces an increased heart rate and respiration rate, excitability, bulging of eyes, etc.

In addition to the clinical value of ascertaining the basal meta bolic rate in certain diseases, it has some practical use in determining the detary requirements of those who are overweight or underweight. The basal metabolic rate furnishes reliable information for estimating the food requirements of overweight or underweight people The basal metabolic rate, like body temperature and blood pressure, is an additional tool which permits the physician to recognize certain types of disease

The value of the basal metabolic rate is shown by the table of selected pathological conditions on page 504

#### SELF-TESTING QUESTIONS

- 4 What is the meaning of basal metabolic rate? How is it determined? How is it read?
- 5 What internal factors affect metabolism?
- 6 Explain one possible difference in the metabolism of two men of the same height of same weight of different ages
- 7 How does the accretion of the thyroid gland affect the basal metabolism (B M R )?
- 8 What clinical and practical value has the basal metabolic rate determination?

#### III. METABOLISM OF CARBOHYDRATES

The nutrients from the digestion and absorption of foods, to gether with oxygen are supplied by the circulation of the blood to the organs and tissues. Here they are used for the production of energy and also for the synthesis of the many substances required by the body, both for its structure and its functioning. The utilization of nutrients to satisfy body requirements invariably involves a series of chemical transformations. For illustration, as will be discussed later, when glucose serves as a source of energy it is not oxidized directly, in one step, to the end products carbon dioxide and water. Rather, it goes through a series of gradual changes so that there are numerous related intermediate steps and intermediate compounds. This is known as intermediary metabolism. This field of biochemistry is being intensively explored, and the discoveries made have been and will continue increasingly to be of great value in coping with disorders of the human body.

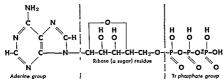
The metabolism of carbohydrates, like that of lipids and proteins, is controlled by enzymes and coenzymes, ho-mones minerals (as ions), and other factors. It is known that some of the vitamins play an essential role in metabolism since they are required for the synthesis of certain enzyme systems.

# The High Energy Bond

It is now generally accepted that the immediate source of energy for muscular activity is a compound called adenosine triphosphate, abbreviated ATP This substance, present in all muscle tissue,

	,		
Known or Suspected Pathological Cond tion	Range of B M R	Accepted Treatment (See references)	Value of B M R
Exephthalmic Gotter	High +15 to +75 and over	Full indimination followed by subtotal thyroid	Metabolana testa halp to confirm dagnosas and
Toxic Adenoma	High., +20 to +75 and over	_	regions Abs of some prognostic
0 4 1 1	Normal -10 to +15	Surposal Indused sait most effective prophy-	Differential diagnous from mild tone goithe is some- times reduced especially in patients with normally
dation (monor) admis	Occasionally low (-20)	Thyroid (U.S P.) 11% gr daily	now from the accomplished by dispused certs with inditive measuring results with metabolism teats. (Ibid p 178)
Myredema	Low -15 to45	Dred thyroid (USP) gland by mouth (Ibid p 259) Dose 135 gr to 3 gr daily	Repeated metabolim tests together with clinical examination helpful in checking efficacy of treat ment.
Cretmien (Early diagnous un perative for satis factory result)	Low -15 to -45	Thyrold (U.S.P.) (That p 271;) 1/5 gr to 13/5 gr depending ou age.	B.M.R. useful with clinical man featations in setab- lishing correct dosage of thyroid (1814 p. 272)
~~~	Normal to raused +10 to +50 Low late in disease (-20)	If metabolam iest shows slivested rate toding may be effect vs to some extent. (Ibid p 113) Di Bom, Basel Metabolam in Health and Disease p 377)	asy be effect ve to some extent. (fold p 113 E F
Ances Hypopitus Larisen	Normal to lowered +10 to20	Possibility of effectiveness of several types of h	Possibility of effectiveness of saveral types of hormones depending on pitu tary deficiency a type (J. H. Menns Thyroid and 1ts Discuses p. 531)
Obesity	Normal to high -10 to +20	Diet restrictions and exercise (75td p. 524)	Thyroid extract sometimes used but requires careful checking of results by metabolism tests as it may cause hyperthyroidum. (1bid p 525)
Endogenous	Normal to low +10 to -20	If test shows B M R is normal thyroid extract v sometimes belpful (16id p 526)	is normal thyroid extract will be of no value. Primitary extract (anternor lobe)
Nervous and Mental Disorders	Normal to low +10 to -30	As required by ind vidual. Reaction of nerv ous patients with low rates to thyroid very varied and unpredictable (Ibid. p. 533)	Metabolum test heipful in differentiating thyrotoxia nervousièses from true effort syndrome
Thyro d Heart	Normal to raused -10 to +30	As for hyperthyrodism. (Work now bang done on treatment of congestive hear failure and angua pectors by thyro dectomy (Ibid p 542)	B M R wil fast to differentiate thyrotoxic heart from true heart disease or thyrotoxicosus super- imposed on heart disease

can release considerable energy through a reaction of hydrolysis which produces adenosine diphosphate, abbreviated ADP, and phosphoric acid Adenosine triphosphate is said to have a high energy linkage in its structure. ATP serves also as a source of the energy needed for promoting some of the chemical reactions of intermediary metabolism, and as a source of the phosphate group for a number of phosphorylations. The chemical structure assigned to this highly important and interesting compound follows. The two vertical broken lines through the formula are merely to show the three structures which are incorporated in the ATP molecule.



The \* indicates the high energy bond. Hydrolysis breaks this bond to release energy and to form ADP and  $H_3PO_4$ 

Much of the energy released in the catabolism of nutrients is stored in muscle tissue as ATP, where it is immediately available for muscular activity.

## Changes Produced by the Liver.

In the course of digestion the carbohydrates are changed into the monosaccharides, glucose, fructose, and galactose, which, after absorption into the capillaries of the intestinal mucosa, are carried by the blood to the portal vein, and thence to the liver. After the blood passes through the liver into the hepatic vein two changes are noticed (a) glucose is the only sugar present, and (b) of more importance its amount has been decreased. This decrease in sugar content is accounted for by the condensation of the monosaccharide molecules under the influence of a group of enzymes to form the polysaccharide "glycogen". This is known as animal starch and is stored as a colloidal and indiffusible product in the liver.

The liver, then, is a very important organ in carbohydrate metabolism since it regulates the amount of glucose which enters the general circulation to be carried to the tissues. This is only one of the many vital functions of the liver. Even though at times the consumption of carbohydrates becomes so large that the sugar content of the portal vein may be twice the normal amount, the liver removes the excess and stores it as glycogen. The excess sugar which is stored temporarily in the liver as glycogen can be changed by enzymes at a moment's notice into glucose for the purpose of contaction in the tissues during fasting. Some glycogen is also found in the tissues, but even that amount, together with glycogen of the liver, does not normally total one pound. This would be consumed in one day of fasting. Therefore it is evident that glycogen provides only a temporary and limited reserve supply of fuel for energy or for muscular work, and for maintaining a somewhat constant glucose concentration in the blood

In the liver the synthesis of glycogen from glucose, called glycogenesis, proceeds as follows

(2) Glucose-6-phosphate Glucose-1-phosphate

Phosphorylase

(3) Glucose-1-phosphate Glycogen + phosphoric acid

The numbers used in some of these names identify carbon atoms in the carbon chain of the molecule. Glucese has a chain of six carbons. The numbering starts with the carbon of the aldehyde end of the chain. Thus in glucose I phosphate a phosphate group is joined to carbon number one by an ester linkage.

A series of reactions similar, if not identical, to those just given occurs when muscle glycogen is formed from glucose withdrawn from the blood. The first of these reactions is not reversible, it progresses only because of the high energy provided by ATP, which serves also as the phosphorylating agent.

When liver glycogen is hydrolyzed to produce glucose, a process called glycogenolysis, the following reactions occur

#### 

(3) Glucose-6-phosphate ———— Glucose + phosphoric acid

When glycogenolysis takes place in muscle tissue, only the first two of the above three reactions take place Muscle tissue contains no phosphatase (glucose 6 phosphatase) to hydrolyze the glucose-6 phosphate

At least two hormones, epinephrine and insulin, play a part in glycogenesis and glycogenolysis. It may well be that these hormones control the activity of the enzymes hexokinase and phos phorylase. Insulin promotes the conversion of blood sugar to glycogen (glycogenesis) while epinephrine has the opposite activity, favoring the hydrolysis of glycogen. Thus if the nijection of too much insulin into a diabetic patient produces hypoglycemia (low sugar), epinephrine can be used to increase the blood sugar and relieve insulin shock.

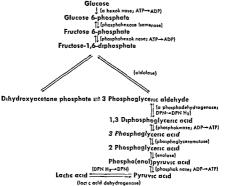
All of the nutritionally important simple sugars, fructose and galactose as well as glucose, can undergo glycogenesis, but glycogenolysis produces glucose only

## Anaerobic Catabolism; Glycolysis

Having noted the part played by the liver in glycogenesis and glycogenolysis we shall next examine the mainter in which glucose (blood sugar) breaks down in the liver, and especially in muscle tissues, to release energy. For purposes of discussion this is considered in two stages, first the anaerobic phase (without air, 1 e oxygen) and second the aerobic phase (in presence of air).

The anaerobic phase of the catabohsm is known also as glycolysis. It includes a series of chemical changes which split the six carbon atom glucose molecule into two molecules of three carbons each Reactions in the series are controlled, ie, catalyzed, by specific enzymes. The diagram on p 508 outlines glycolysis, starting with the glucose which is present in liver and muscle tissue, or which becomes quickly available from glycogen through glycogenolysis.

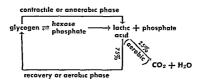
In this series of changes, two molecules of ATP are consumed and four are produced for each molecule of glucose metabolized to pyruvic acid. This is a net gain of two molecules of ATP, which with high energy bonds represents a storage of energy released in glycolysis.



There are two chemical transformations during glycolysis which involve dehydrogenases. These are enzymes, the coenzyme portion of which has the ability to remove hydrogen from the substrate. Once the dehydrogenase has combined with hydrogen transformation as a reducing agent in giving by its hydrogen. The removal of hydrogen is equivalent to exidation. The dehydrogenase of importance here carries the coenzyme called diphosphopyridine nucleotide, abbreviated DPN. Associated with different apoenzymes this dehydrogenase (DPN) becomes a specific dehydrogenating agent, or if in reduced form (DPN Hz.), a specific reducing agent.

To illustrate the activity of DPN and DPN H<sub>2</sub> refer to the last step in the glycolysis process namely the formation of lactic acid from pyruvic acid The equation is as follows

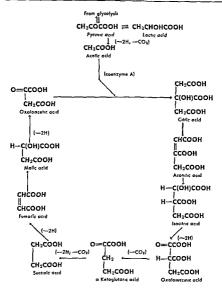
The lactic acid which is produced in the anaerobic phase from pyruvic acid must be promptly disposed of A considerable amount is resynthesized to glycogen during the recovery period following exercise. Particularly after strenuous exercising, lactic acid diffuses from the muscle tissues into the blood, and a small amount of this is excreted in the urine. The larger part is returned to the liver where it is converted to glycogen. Observe that the reactions of glycolysis are reversible, but, in reversing, energy is consumed. The energy needed for reforming glycogen from lactic acid comes from the oxidation of a portion of the lactic acid.



Too violent exercise causes such an accumulation of lactic acid that oxidation cannot take place rapidly enough to provide the energy for disposing of it. An "oxygen debt" exists, and as a result the muscles become so fatigued that they cannot respond to stimuli. Resting and deep breathing soon provide extra oxygen for repaying the oxygen debt

## The Aerobic Phase; Tricarboxylic Acid Cycle:

The lactic acid (or the pyruvic acid from which it is formed), which is not converted to liver glycogen, is metabolized through a senies of reactions which produces ultimately carbon dioxide and water, with release of considerable energy. The mechanism by which this is accomplished is known variously as the Krebs cycle, after the name of the biochemist who proposed it, the citric acid cycle, or the tricarboxylic acid cycle. The following diagram pictures this metabolic cycle.



Careful study of this cycle shows that a molecule of acetic acid is consumed in each trip around the cycle. As shown, the acetic acid which enters the cycle proper originates from pyruvic acid, or its reduction product lactic acid. Each chemical change in the cycle is controlled by a specific enzyme; with one exception their names have not been given. In addition there are five transitions which require dehydrogenases, as indicated by ~2H. The dehydrogeness accept the hydrogen, is indicated, thus ordizing the

substrate Eventually, however, the hydrogen is brought into combination with molecular oxygen to form water, and the de hydrogenase is reactivated Consequently dehydrogenases may be viewed as factors which are "hydrogen carriers"

The union of oxaloacetic acid with acetic acid at the start of the cycle is catalyzed by coenzyme A. This coenzyme brings the acetic acid into an active state (acetyl CoA) for condensation with oxaloacetic acid to form citric acid. It is of interest that pantothemic acid, one of the B vitamins, is incorporated in the structure of coenzyme A.

The over all effect of the tricarboxylic acid cycle is summed up in the following equation

2 
$$C_3H_4O_3$$
 + 5  $O_2$   $\rightarrow$  6  $CO_2$  + 4  $H_2O$  + energy

Pyruv c ac d

The energy derived from the oxidations, with the exception of the heat is used to create high energy bonds through the synthesis of ATP from ADP. It is thought that the aerobic phase of carbo hydrate metabolism provides fifteen times as much energy as the anaerobic phase.

Since it expresses the only way in which nutrients can be completely oxidized, the Krebs cycle can well be considered as a focal point in metabolic processes. We shall find that the intermediary metabolism of fats (lipids) and proteins leads to compounds some of which are identical with those of the cycle. This aids greatly in explaining how the fats carbohydrates, and proteins are in some respects interrelated in metabolism.

# Conversion of Glucose to Fat

It is generally known that eating much candy and sweets causes one to "put on weight" To fatten such farm animals as cattle and hogs, corn and other grains that contain carbohydrates are used to make up the largest part of their food. In both cases, experience and experiment have shown that animals can change carbohydrates into fats and that carbohydrates may be stored as fat in the body. This ability of the body to synthesize fat from carbohydrates is not very simple from a chemical standpoint and at present the process is far from clear. It is known that a fat is a glyceryl ester of a fatty acid. Therefore, in order to form body fat, both glycerol and fatty acids must be synthesized from the excess carbohydrate.

With the facts already stated pertaining to the conversion of glucose to glyceric aldehyde, it is not difficult to postulate how

glycerol might be formed by the reduction of the aldehyde group to the alcohol group

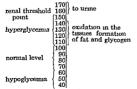
CH<sub>2</sub>OH·CHOH·CHO 
$$\xrightarrow{2H}$$
 CH<sub>2</sub>OH·CHOH·CH<sub>2</sub>OH

Glyce ic oldehyde Glycerol

However, the mechanism of long chain fatty acid formation is somewhat uncertain. Since fatty acids of nutrition always contain an even number of carbon atoms, evidence points to the continued condensation or linking together of two carbon units. The acetic acid of intermediary carbohydrate and fatty acid metabolism represents such a unit. The synthesis of fatty acids may take place via acetyl coenzyme A, although conclusive evidence is lacking.\*

## Carbohydrate Tolerance

We have learned that when carbohydrates are taken into the body a part is oxidized immediately to produce energy, while the remaining portion is stored as glycogen in liver or muscle tissues, or is converted into fat. This capacity of the body to oxidize or store the carbohydrate glucose is called the carbohydrate tolerance. Ordinarily, following a meal which contains carbohydrates, the amount of glucose in normal blood rises from about 100 milligrams of sugar per 100 ml of blood (01 per cent) to approximately 150 milligrams (0 15 per cent) during the first hour and usually returns to normal by the end of the second hour, because the excess blood sugar is either "burnt" (oxidized) or stored as glycogen or fat. In some cases, the blood sugar may run as high as 180 milligrams (0 18 per cent), nearly double the usual amount. Above this blood sugar level, called the threshold point of the kidney, sugar begins to pass into the urine, and gives inse to the condition known as



BLOOD SUGAR LEVEL (in milligrams per 100 ml)

Experiments seem to indicate that this mine (vitamin B<sub>1</sub>) plays an important role in the synthesis of fat from carbohydrates

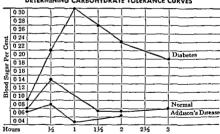
alimentary glycosuria It usually requires the consumption of approximately a pound of sugar to produce alimentary glycosuria in a normal person. This alimentary glycosuria is not pathological but rather an expression of excessive carbohydrate intake

The ability to utilize carbohydrates, that is, to oxidize or store them, is in part controlled by insulin, an internal secretion or hormone of the pancreas Lacking insulin, sugar would simply accumulate in the body An unquenchable thirst for water arises in order to carry this excess sugar from the body Hunger develops, the body steadily loses weight, and there is a lack of muscular energy The mability of the body to secrete an adequate amount of insulin is manifested by a decrease in the carbohydrate tolerance When the blood sugar is above normal, a condition known as hyperglycemia, sugar is usually excreted into the urine When hyperglycemia and glycosuria occur after a normal diet the patient very likely has a disease called diabetes mellitus, and blood sugar values may be as high as 12 per cent In such a condition the vitality of the patient is low because of the mability to store or burn glucose In chronic diabetes the renal threshold for sugar excretion may be elevated and glycosuria may be absent. Con sequently more reliance should be placed on an analysis of sugar in the blood rather than on the presence of glucose in the urine It sometimes happens that the patient's threshold point is lowered and glycosuria occurs even when the blood sugar is normal Such a condition of a low sugar threshold is called renal diabetes. An overdose of insulin commonly brings on the dangerous condition of hypoglycemia (low sugar), often accompanied by convulsions This may be relieved promptly by the administration of sugar

In certain pathological conditions (diabetes, hyperthyroidism, nephrita) the determination of the carbohydrate tolerance has been of the greatest importance in establishing the diagnosis. The procedure is as follows: A blood sample is obtained from the patient after a 14 hour fast, 50 to 100 Gm of glucose are consumed, blood samples are taken at subsequent intervals of 15 to 30 minutes over a period of two or three hours, and the blood samples are all analyzed for sugar. The percentage of blood sugar and the time are plotted as in the diagram on page 514.

The maximum height of the curve and the time required to return to normal levels when compared to healthy patients' response shows the severity of the disease In a normal curve the maximum sugar concentration is highest near the end of the first hour but it returns to normal in about two hours. A diabetic curve, however, shows both a greater rise and slower fall. The shape of the curve, drawn by plotting sugar percentages against the time after ingestion of glucose, is of great disagnostic value, especially for the detection of early stages of diabetes; but in using the assimilation curve, it is well to keep in mind that its shape may be altered by such various factors as sugar absorption from the intestines, sugar retention by the liver, and sugar consumption by the tissues. This is particularly significant after prolonged starvation (24 hours or more). The change of glucose into glycogen by the liver is largely dependent upon a group of enzymes, presumably elaborated by the liver cells. Some of the glycogen comes from the absorbed sugar, as has been stated, and some is produced from the glycerol fraction of fats and some from protein. Thus there is always some glycogen in the liver.

#### DETERMINING CARBOHYDRATE TOLERANCE CURVES



The consumption of sugar by the tissues has already been explained. It should be remembered that diabetes mellitus is due primarily to a loss of power on the part of the tissues to utilize sugar. The normal functioning of carbohydrate metabolism in the muscles and other tissues is an important factor in maintaining a healthful body.

Refore leaving this discussion we should understand that there are several forms of temporary glycosuria. One condition, alumentary glycosuria following the ingestion of excessive carbohydrate intake, has been mentioned. Another form, stemming from mental strain or great agitation, is called emotional glycosuria, and un-

doubtedly is caused by the production of excessive epinephrine, which is always secreted under emotional excitement. It is at such times that the muscles need an increased fuel supply

#### SELF-TESTING QUESTIONS

- 9 What two changes take place when blood passes through the liver?
- 10 How do you account for a decrease of the glycogen content of the liver?
- 11 What changes are believed to occur during the oxidation of glucose?
  - 12 What happens to the lactic acid formed during glucose oxidation?
  - 13 What causes muscle contraction?
- 14 To form body fat from glucose what two classes of intermediate sub stances must be formed?
- 15 What is meant by carbohydrate tolerance and threshold point?

  16 What factors may alter the shape of an assimilation curve?
- 17 How would you interpret the assimilation curve for sugar?
- 18 What controls the secretion of blood sugar by the liver?

#### IV. METABOLISM OF FATS

# **Functions of Fats**

In the course of digestion of fats, the glycerol and fatty acids formed are absorbed by the epithelial cells of the villi and are re combined in their passage through the intestinal wall to form neutral fats, which are absorbed by the lymphatic vessels These are drained by the thoracic duct which empties into the venous system at the junction of the left jugular and subclavian veins In the form of an emulsion, the neutral fats are carried to the cells where they may be (a) oxidized immediately to furnish energy. (b) stored in the tissues as a reserve fuel, and (c) transformed into lipids, fatlike substances that form an essential part of every cell and which are not depleted even during exhaustive starvation Formerly, the cell membrane was thought to be entirely composed of proteins, but it is now known that fats in combination with proteins (hipoproteins) form very complex substances These are believed to be an integral and essential part of cell membranes of cellular protoplasm, and of the central nervous system. In this sense fats as well as proteins are tissue builders

Two very well known lipids are legithin and cholesterol Lecithin, one of the phospholipids, apparently is an intermediate compound formed in the metabolism of fat Cholesterol is a solid alcohol of high molecular weight and belongs to a group of derived lipids called sterols. It, like legithin, is connected with fat metabolism in some as yet unexplained manner. In some instances it has a clinical significance. An excess of cholesterol in the blood is suggestive of gall stones, diabetes, pregnancy, and certain renal disorders, especially

nephrosis In the skin, cholesterol is associated with ergosterol, which upon exposure to sunlight or other sources of ultraviolet rays is converted into the antiractuit factor, vitamin D Food products may also be randinted because they contain ergosterol

#### Oxidation of Fats

Although much is yet to be learned about the lipids in cellular structures, we do have considerable information concerning the oxidation of fat in the production of energy. Fats must first be split into glycerol and fatty acids before oxidation may take place. The splitting is a hydrolytic action probably performed by tissue lipases. A glance at the formulas (CH\_2OH CHOH CH\_2OH) shows that glycerol, like glucose (CH\_2OH (CHOH), CHO), has representative alcohol groupings of fats acts in a manner similar to glucose, and, upon oxidation produces glyceric aldehyde which is one of the intermediate products in the glycolytic phase of glucose metabolism (p. 508). Since glycerol accounts for about 10 per cent of the weight of fat it can be said that thus amount of the total fat which is metabolized for energy follows the carbohydrate route of metabolism. Such data are important in dietary studies.

The fatty acids which are released from fats by hydrolysis are oxidized in stages giving ultimately, in a normal metabolism, carbon dioxide and water as material products. The most widely accepted views as to how this takes place are based on Knoop's theory of beta (\$\beta\$) oxidation. Here it is supposed that the oxidation first sets in at the beta carbon of the fatty acid chain. As learned previously, the beta carbon is the second one after the carboxyl carbon. Using steams acid for illustrative purposes the following formulas depot the course of the oxidation.

 $\begin{array}{c|cccc} CH_3 & CH_3 & CH_3 \\ (CH_2)_{14} & (CH_2)_{14} & (CH_2)_{14} \\ \hline (CH_2)_{14} & O & O \\ \hline (CH_2)_{14} & (CH_2)_{14} \\ \hline (CH_2)_{14} & O & O \\ \hline (CH_2)_{14} & (CH_2)_{14} \\ \hline (CH_2)_{14} & O & O \\ \hline (CH_2)_{14}$ 

$$\begin{array}{c|cccc} CH_3 & CH_2 & COOH & COOH & COOH & Acet c acd & COOH $

The net result of this sequence of reactions is to produce a molecule of acetic acid and one of palmitic acid, the latter having two less carbon atoms in its chain than the original stearic acid. By a repetition of these reactions palmitic acid will split off a two carbon atom fragment, as acetic acid, and give CH<sub>3</sub>(CH<sub>2</sub>)<sub>12</sub>COOH. This acid can then give rise to CH<sub>3</sub>(CH<sub>3</sub>)<sub>12</sub>COOH and so on until all intermediates have been oxidized to acetic acid. Coenzyme A plays an essential part in these oxidative changes, and actually the acetic acid molecules which are produced appear in activated form as acetyl coenzyme A. Recall that acetyl coenzyme A enters the tricarboxylic acid cycle to be oxidized to carbon dioxide and water, with release of energy

Notice that the formation of acetic and, a two carbon atom molecule, as the end product of fatty and degradation, requires that the original fatty and have an even number of carbon atoms in its chain. It is interesting to note that this is actually the nature of those fatty acids, which, in the form of glycendes, comprise our natural fats and oils, odd numbered carbon chains are not found

In Knoop's proposal the oxidation follows the usual course, namely secondary alcohol to ketone, followed by splitting to form acids

Other mechanisms of fatty acid oxidation have been proposed, one of these being the multiple alternate oxidation theory. According to this scheme, oxidation of the fatty acid occurs simultaneously on the beta carbon, and on every alternate carbon from this point throughout the length of the chain, to give an acid with multiple ketone groups. Hydrolysis, with splitting, then takes place at the points of oxidation

# Incomplete Fat Metabolism

The compounds \$\beta\$ hydroxybutyric acid, acetoacetic acid, and acetone are formed in abnormal amounts when fats fail to metab olize properly To understand how these compounds are produced,

recall that in Knoop's theory of beta exidation the carbon atoms are removed two at a time as acetic acid from the original fatty acid alenved from natural foods have an even number of carbon atoms there will be produced ultimately during the exidation a four carbon atom acid, normal butyric acid Normally this would exide and break down as follows

$$\begin{array}{c|cccc} CH_3 & CH_3 & CH_3 \\ CH_2 & O & CHOH & O \\ \hline CH_2 & CH_2 & CH_2 \\ \hline COOH & COOH & COOH \\ n \ butyr c \ ac \ d & \beta \ Hydroxy \\ \hline CH_3 & CH_3 & CH_3 \\ \hline CH_0 & O-H & COOH \\ \hline Then, & CH_2 & H & CH_3 \\ \hline COOH & COOH \\ \hline COOH & C$$

In faulty fat metabolism, however,  $\beta$  hydroxybutyric acid, acetoacetic acid, and acetone (the latter formed from acetoacetic acid upon loss of carbon dioxide) accumulate in the tissues and blood. These three compounds are related as follows

$$\begin{array}{ccccc} \mathsf{CH_3} & \mathsf{CH_3} & \mathsf{CH_3} \\ & \mathsf{CHOH} & \bullet & \mathsf{CCO} \\ & \mathsf{CH_2} & \mathsf{H} & \mathsf{CH_2} & & \mathsf{CH_3} \\ & \mathsf{CH_2} & \mathsf{H} & \mathsf{CH_2} & & \mathsf{CH_3} \\ & \mathsf{COOH} & \mathsf{COOH} & & \mathsf{Acctione} \\ \beta \ \mathsf{Hydroxybutyric} \ \mathsf{cs} \ \mathsf{cd} & \mathsf{Acctione} \end{array}$$

Collectively they are known as the "acid bodies" although only two of them are actually acids. Their formation reduces the alkalinity of the blood and tissues and in severe cases the resulting acidosus may lead to coma and even death.

Faulty fat metabolism is associated with an inability to properly metabolize carbohydrates. In severe diabetes, when glucose is not properly stored and oxidized, a form of acidosis commonly called ketosis (formation of acid bodies) occurs. In fact, the senous aspects of diabetes mellitus in the advanced stages can be attributed to the accumulation of acid bodies. The statement that "fats burn in the flame of carbohydrates" colorfully sums up the dependency of proper fat metabolism on a normal carbohydrate metabolism. Apparently an incomplete metabolism of glucose gives insufficient intermediates for the operation of the tricarboxylic acid cycle. Acetic acid cannot be disposed of by the cycle, and therefore the breakdown of fatty acids stops with the formation of four carbon atom products. It is possible that some of the acetic acid which is produced before the four carbon atom stage is reached is used up in synthesis of acid bodies, inasmuch as its normal metabolism is blocked. Acid bodies also appear during prolonged starvation. Here the carbohydrate reserve of the body has been depleted, and energy is realized largely through the extensive catabolism of fatty tissue.

# Ketosis and Antiketosis

The fatty acids, and those amino acids which can metabolize to give "acid bodies," are called ketogenic foods (keto=ketosis, genic=formation) Foods such as glucose, glycogen, glycerol, and those amino acids which metabolize as do the carbohydrates, are the antiketogenic foods, these favor normal oxidation of the fatty acid fragments, thereby preventing ketosis When ketosis is due to starvation it is relieved by increasing the carbohydrate diet. In diabetes, ketosis is controlled by correcting the carbohydrate metabolism, often by the use of insulin

About 58 per cent of the protein food provides amino acids which can be metabolized like carbohydrate. Also, 10 per cent of the fat eaten (glyceryl fraction) metabolizes like glucose. Therefore, in calculating the available carbohydrate in any diet, one always sets the total carbohydrate as equal to (1) 100 per cent of the dietary carbohydrate plus (2) 58 per cent of the dietary protein plus (3) 10 per cent of the dietary fat. It follows then that a diabetic diet should include (a) no more food than is needed for normal energy requirements, (b) as little protein as is required to maintain the nitrogenous equilibrium, a condition during which mitrogen excreted equals the amount taken in by food, and (c) the correct proportion of glucose to fat

#### SELF-TESTING QUESTIONS

- 19 What three things may happen to emulsified fats on reaching the cells?
  20 What is the clinical significance of an excess of cholesterol?
- 21 In what way is cholesterol important?
- 22 What probably happens to glycerol on oxidation?

- 23. What are the products of faulty fat metabolism?
- 24. What is ketosis?
- 25. What is an antiketogenic substance? Name one.
- 26. How may ketosis be relieved?
- 27. How may it be prevented?
- 28. What are the dangers of fasting?
- 29. What causes obesity?

# V. METABOLISM OF PROTEINS

# Function of Amino Acids:

In the course of the digestion of proteins, the amino acids formed are absorbed through the intestinal wall, passing unchanged into the blood of the portal vein, and via the liver enter the general circulation for distribution to the various tissues of the body. In this circulation, each tissue has the power of selecting the number and kind of amino acids required by that particular tissue. It has been found that there are at least eight amino acids which are essential



Fig. 4.—Amino acids, the structural units of proteins. This picture shows some of the scientists who have synthetized from coal and other materials the amino acids that must be included in our deet. How many of these acids are essential in the diet? Courters, Dow Chemical Co.

in the diet to maintain the growth and repair of the tissues. These are called "essential" because they cannot be synthesized in the body from other amino acids. Common food substances like eggs, milk, and meat contain a sufficient supply of these amino acids, but some cereal proteins are low in lysine and tryptophan, two of the so-called essential amino acids. Zein, for instance, a protein from corn, contains no tryptophan or lysine. Even gelatin lacks trypto phan and tyrosine, and if either of these two proteins were the sole source of protein in an otherwise adequate diet, the animal would die as certainly as if he were receiving no protein at all

The absorbed ammo acids are available to provide for growth or repair of the protein structure of the cells, those which are not used for this purpose undergo deamination, a process involving the splitting off of the nitrogen containing ammo group (NH<sub>2</sub>) to form ammonia, while the rest of the molecule, containing only carbon, hydrogen, and oxygen, is either oxidized directly to furnish energy or if sufficient quantities are present, may be converted into glucose and fat

#### Oxidative Deaminations

In decided contrast to carbohydrates and fats, proteins cannot be stored as protein in the body except in very small amounts. This means that any excess of amino acids not required in tissue con struction must be used as fuel or stored as glycogen or fat

Amino acids formed by the decomposition of the protein mole cules apparently are subjected to oxidative deamination reactions, principally in the liver and kidney Oxidation takes place at the alpha carbon to form the corresponding imino acid. This acid probably forms an unstable hydrate, which decomposes to yield a ketonic acid and aminomia as illustrated in the following equation

$$\begin{array}{c|c} R & R & R & R & OH & R \\ \hline \alpha CH & NH_2 & \rightarrow C = NH & \rightarrow C \\ \hline COOH & COOH & COOH & COOH \\ Amino & In no & Hydrote \\ cold & cod & cod \\ \end{array}$$

Ammonia split off in the deamination of an amino acid and the carbonic acid of the tissues, by means of a cyclic reaction in the liver, unite to form urea, as will be explained later

#### Transamination:

In addition to oxidative dearmination, amino acids may also free themselves of amine groups by transamination. This requires the presence of an alpha keto acid, to which the amine group is transferred

Notice that transamination results in an interchanging of structures. In the example given, aspartic acid transfers its ammo group to pyruvic acid thus becoming oxaloacetic acid, and producing a new amino acid, alanine. Inasmuch as pyruvic acid, an intermediate in carbohydrate metabolism, and aspartic acid, an amino acid in the composition of many proteins, react in this manner, the product alanine is not an "essential amino acid" in the diet. Body require ments for alanine can be met, if necessary, by its formation in the body via transamination.

Reactions of transmination make it possible for the body to synthesize certain needed amino acids from others, providing the necessary keto acids are available. Also, as this discussion has implied, transamination definitely links the metabolism of proteins with that of the carbohydrates. Transamination, and oxidative deamination as well, produce a number of compounds which are also found in the tricarboxylic acid cycle.

#### **Urea Formation**

The ammonia which is produced in the deamination of amino acids is disposed of largely through conversion into urea, a process which can be summarized as follows

$$2 \text{ NH}_3 + \text{CO}_2 \rightarrow \text{C=O} + \text{H}_2\text{O}$$

$$\text{NH}_2$$
Urea

The synthesis of urea from ammonia and carbon dioxide takes place in the liver. Actually it is a far more complex process than it appears to be as expressed in the equation

Investigators believe that three amino acids are involved in the process; ornithine, citrulline, and arginine. The reactions which make use of these amino acids for the production of urea are indicated by the followine equations:

This sequence of changes, which indirectly converts ammonia into urea, is called the *ornithine cycle*, since it begins and terminates with ornithine. After its formation in the liver the urea is carried by the blood to the kidneys and then excreted via the urine. About 80 per cent of protein nitrogen excreted from the body is in the form of urea. This amounts to up to 30 grams of urea for an adult over a 24 hour period.

The digestion and metabolism of those proteins which contain sulfur and phosphorus lead to the production of morganic acids of these two nonmetals. Some of the ammonia produced in the deamination of the amino acids neutralizes such morganic acids by converting them into ammonium salts. These are then excreted by way of the urine.

# Nitrogen Balance

Since protein cannot be stored and must be excitized to yield mitrogenous waste products, it follows that in certain cases of impaired kidney function low protein diets appear to be indicated However, if the diet is too low in protein and the loss of protein by damaged kidneys is great, or if the protein eaten does not contain the essential amino acids, a negative mitrogen balance results, i.e., more nitrogen is excreted than is present in the food consumed. This may prove more detrimental than the accumulation of mitrogenous wastes in the blood, and the problem must be left to the physician. A positive balance exists when the amount of mitrogen in the consumed protein is greater than that in the excretion, e.g., in growing children. Ordinarily for a normal adult the total mitrogen in the food eaten just equals that excreted into the urine, feces, and perspiration, and a state of nitrogen equilibrium exists.

Before leaving this subject, attention should be called to the effect of a low carbohydrate diet. In fasting, or when an individual east less to lose weight, the normal supply of carbohydrate may be greatly diminished with the result that the supply of glycogen is soon used up Consequently, at such times most of the energy comes from body fat, and the acctone bodies appear

Usually, obesity is the result of overeating or lack of sufficient exercise. There may also be a hereditary factor. It is common knowledge that many thin people eat well and do not take on fat, whereas fat people take on weight. The thin people probably exercise more, eat less high calorie food, and drink less water than do fat people. It is an overlooked fact that unless an individual has

been on a diet for a long time water replaces fat in his tissues. It has been established clinically that faulty functioning of the endocrine glands may be associated with obesity.

The following chart summarizes some of the normal metabolic changes of carbohydrates, fats, and proteins.

#### SUMMARY OF NORMAL METABOLIC FOOD CHANGES

Food Carried To Tissues as	Anabolism or Constructive Metabolism	Catabolism or Destructive Metabolism	End Products of Metabolism
Glucose	Glycogen Fat	Aldehydes and acids of three carbon atoms	→CO <sub>2</sub> + H <sub>2</sub> O
Fats	Adipose tissue Lipids	Fatty acids, by β oxidation or by multiple al ternate oxida tion to	CO <sub>2</sub> + H <sub>2</sub> O
	Tissue protein Fat Glucose	Glycerol	-Urea
Amino acids e g , alanine		Non nitroge nous part of molecule (C, H, O)	-CO <sub>2</sub> + H <sub>2</sub> O

#### SELF-TESTING QUESTIONS

- 30 What foods have a sufficient supply of the eight essential amino acids required in a diet?
- 31 What happens to amino acids in absorption?
- 32 What is the meaning of deamination?
- 33 What is transamination?
- 34 Explain what happens in the formation of urea from ammonia
- 35 Where is urea reconverted to ammonia in the body and why?
- 36 What salts are likely to occur in urine?
- 37 How is the total available carbohydrate, from a mixed diet (i e, con taining fat, carbohydrate and protein) calculated, and when is such a calculation of practical value?

#### VI. METABOLISM OF INORGANIC SALTS

#### Classification of Inorganic (Ash) Elements

We have been studying the metabolism of foods that supply energy and build tissue. In addition to these body requirements, there is a need of other maternals that will help regulate body processes and make possible normal metabolism. These are the morganic or mineral constituents of food substances. By morganic substances is meant the inorganic salts (NaCl, CaHPO<sub>i</sub>, etc.) which enter and leave the body as such, as well as other mineral constituents such as the iron in hemoglobin, and the phosphorus and sulfur in protein, which are in combined form with organic matter and which upon oxidation are eliminated as morganic salts. The morganic substances with which we are primarily concerned include the elements Na, K, Ca, Mg, Fe, existing mostly as chlo



Fig 5—Osteomolac a Depletion of mn erals causes the long bones to become soft flex ble and badly deformed Besides a calcum and phosphorus deficiency what other factors may be operating to produce osteomolac a?

rides, phosphates, bicarbonates, and in a lesser amount as iodides and sulfates

It is convenient to classify the ask elements of the body as an acid group (S, P, Cl) and an alkali group (Na, K, Ca, Mg) A third group, consisting of iron and iodine, is best considered in a separate category as two elements that are found chemically combined in important organic substances such as hemoglobin and thyroxine A fourth group includes the so called trace elements (F, Cu, Mn Co, N, Al, Si, Bi, etc.), whose functions are not completely understood

Each morganic element in the first three groups is needed for growth Experiments have shown that rats do not grow, and eventually die, if the sodium or the potassium is markedly reduced in their diets. Lack of sufficient calcium and phosphorus also inhibits growth and may produce rickets and osteoporosis of the long bones (Fig. 5). A deficiency of chlorine and magnesium also impairs health. In respect to the "trace elements" it is difficult to say whether the presence of some of them in the body is incidental or essential, although recent experiments have suggested a role for both copper and manganese. It is also interesting to note that, as later explained, all of the mineral elements may be utilized if in the form of simple morganic salts with the exception of sulfur Available evidence indicates that the body can utilize only the sulfur of the amino acids, cystine and methionine. Of all of these elements, the ones that are most apt to be deficient in the human diet are calcium, phosphorus, iron and iodine, and because of their known importance in nutrition, special attention is given them as the separate elements are described.

# General Functions of Inorganic Salts

With the exception of the phosphates of calcium and magnesium, all of the morgame salts are soluble in water and consequently usually occur as tons in the body's fluids wherein they perform special functions. Even though the inorganic salts are almost en tirely unoxidizable, or are in the oxidized form, and do not furnish heat or energy, nevertheless their importance to life and health may be appreciated as one considers their chief physiological uses. The general functions of the morganic salts, briefly stated and later explained in more detail, are these

- 1 They contribute to the building and repair of tissues
- 2 They influence the contraction of muscles and irritability of nerves
- 3 They help to maintain proper osmotic conditions
- 4 They are largely responsible for the acidity and alkalimity of digestive nuces
- 5 They are important factors in the chemical reactions of the body

INORGANIC SALTS BUILD AND REPAIR TISSUES The following table shows that carbohydrates, fats, and proteins furnish approxi-

mately 96 per cent of the elements required in human nutrition, and that the remainder must be supplied to the body as inorganic salts, or as organic salts containing some of these elements

#### COMPOSITION OF HUMAN BODY

	Арргохіта	te Percentag
	Oxygen	65%
Mostly found in carbohydrates	Carbon	18%
fats and proteins	Hydrogen	10%
•	Nitrogen	3%
	Calcium	15%
	Phosphorus	10%
	Potassium	0 35 %
	Salfar	0 25 %
	Sodium	0 15%
Mostly found in nuneral salts	Chlorine	0 15%
	Magnesium	0 05%
	Iron	0 004%
	[ Iodine	0 00004 %
	Si and other elements in traces	

Practically all of the elements required for nutrition are found in sufficient quantities in the average well balanced diet. This in cludes sodium chloride, which is added as seasoning, largely be cause many foods—especially vegetables—are made more palata ble by its use A good diet includes milk, fruits, vegetables, protein food such as eggs, fish, meat, and cereal products made from whole grains. In periods of growth, during convalescence, and in preg nancy, particular attention must be given to the mineral con stituents of foods, for it is well known that minerals are needed to build tissues and the bony structure of the body During normal adult life, there is less need for minerals, but we should not forget that the body is constantly undergoing change, that nutrients are being used up for repair, and that products are being eliminated from the body as salts in the urine, perspiration, and feces. Con sequently, mineral elements must be supplied to maintain normal metabolism However, a proper diet, especially one that is varied sufficiently, contains all the minerals required to maintain good health

Calcium This element, in the form of calcium phosphate, makes up the larger part of the mineral matter of the bones and teeth. An madequate supply of calcium (and phosphorus) in the diet of growing children results in poor skeletal development (osteoid tissue) Any prolonged deficiency of calcium in children results in rickets, a disease which is associated with growth, and is character ized by such types of bone deformity, as bow legs, knock knees, enlarged joints, beading of the ribs, pigeon breast, deformed skull and pelvis However, calcium deficiency is not the sole cause of rickets An adequate supply of phosphorus and vitamin D is es sential Growing children require twice as much calcium as that needed by an adult, because of the rapid growth of the skeleton

In pregnancy a continued deficiency may induce softening of the teeth and bones (osteomalacia), but again, calcium deficiency is not the only cause During pregnancy and nursing, the calcium requirements are three times the normal requirement of an adult At such times, a generous supply of milk and leafy vegetables in the diet provides the needed calcium and vitamins. This deficiency may also be met by certain inorganic salts of calcium as well as the organic forms of calcium, but adequate vitamins are equally important

The functions of calcium in producing depression of muscular irritability, increasing blood pressure, increasing rate of respiration. in maintaining the proper rhythm of the heart, in forming insoluble calcium paracaseinate (milk clot) from casein, in clotting the blood (p 447), and in contracting the cardiac muscle (p 191) have already been discussed. Much has yet to be learned about the role of calcium in metabolism. Milk and cheese are the best sources of calcium for normal requirements

Phosphorus This element is so closely related to calcium metab olism that they are usually considered together Phosphorus, like calcium, is associated with bone growth and the diseases, such as osteomalacia, resulting from its deficiency It is an essential com ponent of every cell in organic form as in the phospholipids and nucleoproteins In the blood, one form of organic phosphorus is associated with the fat content Lean meats and grains are rich in phosphorus, but unfortunately three fourths of the phosphorus is lost in processing flour Besides being a limiting factor in the development of bone and growth, a phosphorus compound is es sential in the clotting of blood Inorganic phosphates are useful as buffer salts for maintaining the acid base balance in the blood.

urine, and probably in the cells. A condition known as osteophagia is due to phosphorus deficiency and is readily cured by the addition of any form of phosphorus to the diet.

Magnesium This element, like calcium, occurs largely in the bones, and plays a role in muscular contraction. Very little is definitely known concerning its specific functions. Pharmacologically, it is known that magnesium salts depress motor and sensory activity, that oral administration causes catharsis, diuresis, and acidosis, and that animals kept on a magnesium free diet developed severe muscular weakness and died, usually after a series of tonic clonic convulsions.

Sodium and Potassium These elements are closely related in their properties and are usually considered together. Both play an important role in the growth and repair of tissue Experiments have shown that growth is not materially affected on a low sodium potassium diet, but in the absence of potassium, growth ceases According to some authorities the potassium that occurs abun dantly in all vegetables tends to modify or increase the elimination of sodium. Low blood potassium has been reported in chronic nephritis and during the post acidotic states of diabetic come. For other uses of some of these elements in the body refer to page 188

Iron Although making up only 0 004 per cent of the body, iron is one of the most important elements in nutrition, for it is a constituent of the hemoglobin of the red corpuscles which carries oxygen to the cells. Iron as a constituent of intracellular pigments, collectively called cytochrome, also acts as a catalyst in certain tissue reactions. Hemoglobin functions as an important buffer of the blood, in addition to its prime function of carrying oxygen. A deficiency of ron produces an anemic condition, such as occurs in chlorosis in women. Iron is abundant in green vegetables and in meat. The chemistry of the relation of due to regeneration of blood in anemia is not yet thoroughly understood. Some beneficial results in producing hemoglobin have been obtained by feeding organs rich in iron such as liver and heart.

According to some authorities, the iron stored in the human liver and that needed for hemoglobin formation is more readily utilized in the presence of small amounts of copper Experimental evidence furnished from a study on rats showed that small amounts of copper stimulated the utilization of iron for hemoglobin formation Furthermore, with a complete absence of copper the iron was ineffective in curing the anemia

Iodine As a constituent of thyroxine, the active principle (hor mone) of the thyroid gland, iodine is of great importance in maintaining a normal rate of metabolism. Iodine is found in nutritional amounts in vegetables, especially those growing near seacoast districts, and in seafoods, particularly in the liver of fish (halbut, cod) When there is a deficiency of iodine, an enlargement of the thyroid gland develops which is known as simple goiter. The use of salt containing sodium iodide has met with considerable success in the treatment of many cases of simple goiter, especially during adolescence.

When there is an overproduction of thyroxin, as in exophthalmic there, the use of iodides is contraindicated. This disease is marked by a high basal metabolic rate. However, iodine does lower the basal metabolic rate for a time and may be safely used (only by the physician) in preparing patients for operation (extirpation of part of the thyroid gland)

'Trace' Elements The remaining mineral constituents (F, Cu, Mn Zn Co Ni, Al Si etc) or so called trace elements, may be grouped together They are usually found in small amounts, and have very little effect on the acid base balance of the body Their functions are still largely unknown

Copper As has already been stated, copper is said to favor the conversion of inorganic iron stored in the liver into hemoglobin Only a trace of it is necessary for this purpose Copper has been found in all tissues, and is particularly abundant in liver

Manganese This element is widely distributed, and traces of it are claimed to be needed for normal growth and reproduction

Fluorine This element occurs in some natural waters as fluorides When it is present in water in excess of 1½ parts per million, it causes a mottling of the skin (brown stained spots) and irregular formation of the teeth of children who drink the water during the period of tooth formation. These dental defects persist throughout life. It has been observed that fluoride in drinking water also has a tendency to decrease the incidence of dental caries. Experiments have indicated that water which contains about one part per million of fluoride does not produce mottling but does have the desirable effect of decreasing dental decay.

Zinc Aluminum These and several other trace elements are found in the body, but their role in metabolism and growth is still somewhat obscure

# Control of the Contraction of Muscles and the Irritability of Nerves

The large muscle of a frog's leg with the sciatic nerve attached has the power of contracting for some time after being removed from the body, providing that the perve is excited by some appropriate stimulus such as the electric current. During the intervals of stimulation the muscle shortens and thickens, then relaxes, the entire process taking place in a fraction of a second. The response to the stimulus soon becomes more feeble, and in a short time the muscle will cease to contract. However, if the muscle nerve prepa ration is immersed in Ringer's physiological saline solution (a solu tion containing the same percentage of sodium chloride and salts of calcium and notassium as occurs in the blood) the muscle will undergo a series of contractions for a longer period of time. It has also been shown that any change in the relative proportions of these salts causes a corresponding change in the response of the nerve and the muscle to stimulation Furthermore, experimenta tion has shown that calcium salts produce contraction, and that sodium and potassium salts cause relaxation. In a similar way in the body the metallic ions. Ca<sup>++</sup>, Na<sup>+</sup> and K<sup>+</sup> of the blood play a role in nervous and muscular activities. As a further contribu tion to these experiments, Ringer found that heart muscle, after removal from the body, could not only be kept beating for hours in this prepared salt solution, but that minute changes in concentration of the Ca++ and K+ may affect the activity of the heart In other words, it is now definitely established that the contraction of muscles and the irritability of nerves are influenced by the concentration of the Ca++, Na+, and K+ ions, and by their relative proportion As an example of what may happen when the balance between the ions is abnormal, we may take the case of tetany, a disease char acterized by twitching or muscular contractions. An examination of blood in such a patient shows low calcium concentration in pro portion to the other ions present, a condition which may be re heved by intravenous injection of calcium salts, or the assimilation of foods high in calcium, as milk. The parathyroid glands play an important role in calcium metabolism

## Maintenance of Osmotic Pressure

It will be remembered (p 101) that osmotic pressure is the force exerted by molecules or ions in solution. Osmotic pressure in the living body is manifested through membranes separating tissues and cells, and water always tends to pass toward the more con centrated solution. Since osmosis is the result of the dissolved particles, the greater the number of dissolved particles the greater will be the osmotic pressure.

If the concentration of salts in the tissues is greater than in the lymph which bathes them, water tends to pass into the tissues, while if the concentration in the cells is less, water passes out of the tissues. The capillary endothelium acts as the membrane. Within a short space of time these differences in osmotic pressure are equalized not merely because of the passage of the water molecules, but also because of the passage of some of the salt ions. It is in this way that nutrients are carried in solution from one tissue to another.

The colloidal material of the cells contributes to the osmotic pressure, but the pressure from the colloidal particles is much less, ow mg to the relatively small number of colloidal particles as compared to the salt ions. Other factors may also contribute to osmotic pressure. The concentration of water molecules in tissues is determined by the attraction of the water molecules for the dissolved mole cules, although in reality this is merely due to a constant tendency to attain osmotic equilibrium.

# Role in Acidity and Alkalinity of Digestive Juices:

In the study of digestion we learned that enzymes are very sen sinve to the medium in which they are contained, some functioning best in a weak acid solution (pepsin in gastric juice), some best in a dilute alkaline solution (lipase in pancreatic juice), and some best in neutral solutions (ptyalin in saliva). In all cases, the sight est variation from normal conditions tends to inhibit the action of these enzymes. The acid in the gastric juice is hydrochloric acid. In the intestine the alkali is chiefly solution bicarbonate. The blood is slightly alkaline and the urine is frequently acid.

# Preservation of Normal Chemical Reactions:

As just stated, any variation in acidity, alkalimity, or neutrality affects certain enzyme reactions. Such a variation may also affect every cell and organ in the body. Acids are constantly being formed as a result of normal metabolism of body tissue and food. Thus from proteins alone we may have carbonic acid formed from carbon, suffuric acid from sulfur, and phosphoric acid from phos.

phorus The carbonic acid, being very unstable, decomposes readily and may be eluminated as carbon dioxide through the lungs The sulfuric and phosphoric acids, being stable and strong acids, would soon mure the cells, but they always exist as salts

One protective device against too much acid or alkali in the blood is the presence of the buffer salts (including proteins) as explained on pages 185 to 187

Part of the proteins through deamination form ammonia, which also assists in neutralizing acids. The ammonium salts of these acids are then excreted in the urine

#### SELE-TESTING OUESTIONS

- 38 How are the ash elements classified?
- 39 What elements are most likely to be deficient in common foods?
- 40 State five functions of inorganic salts
- 41 What foods in particular should be included in a sensible diet?
- 42 What are the functions of Ca P, Mg Na K?
- 43 What importance is attached to the presence of copper?
- 44 What happens when there is a deficiency of or an oversupply of, iodine in the body?
- 45 What common foods contain iron?
- 46 How can iron in the liver be more readily available?
- 47 What is Ringer's solution?
- 48 How does Ca++ on the one hand and Na+ and K+ on the other affect muscles?
- 49 What factors influence contraction of muscles and irritability of nerves?
- 50 What are the sources of the ions necessary for acid or basic solutions in the body?
- 51 What acids are formed in normal metabolism?
- 52 What happens to them?
- 53 What protective devices prevent too much acid from accumulating in the body?

#### VII. METABOLISM OF WATER

# Adaptation of Life to Water.

Life, originating as a single cell in water, first had to develop a mechanism to separate it from its all perioding medium and prevent its dispersion in that medium. This mechanism, was a covering and protecting membrane through which the cell obtained its food and excreted its waste. Life, in the beginning, was dependent on water for everything—food, heat, and mobility. As life developed into more complex forms, it moved its habitat from water to wet mid-

and then to dry land These complex life organisms were less dependent on an immediate source of water

Finally birds and mammals, capable of remaining alive for several days without ingesting any water, evolved. In this period of evolution, the birds and mammals developed a second mechanism for maintaining a constant internal body temperature. This came about in adapting the external protective covering, the skin, to prevent the undue loss of water through evaporation. A frog, for instance, removed from its environmental pond and placed into a hot, dry room, dies from desiccation because its skin is unable to control evaporation.

Another mechanism for the maintenance of constant body temperature has come into the possession of the higher forms of life. This is the ability of the skin to allow the vaporization of large quantities of water when desirable. This is accomplished through the sweat glands. There is a close relationship between water metabolism and animal heat. A constant body temperature is necessary for normal functioning, even though the production of heat within the body varies. This is accomplished by removing excess heat through direct radiation and conductivity into the air, and by the vaporization of enough water to rid the organisms of the heat not disposed of by the other two methods.

The higher forms of life that have evolved from the primitive unicellular form are still absolutely dependent upon an outside supply of water which serves these important functions (a) maintains a constant body temperature, (b) keeps the ratio between solids and liquids constant, (c) aids in digestion, and (d) assists in ridding the body of waste matter.

# Water Exchange:

The body's organism is supplied with water from two widely separated sources. On the one hand, it takes in water contained in the solid food and enough other liquid so that the water content of the two added together satisfies its thrist. Another source is the water that is constantly being formed within the body as an end product of chemical reactions. The foodstuffs all contain hydrogen. When they are consumed, most of the hydrogen combines with the oxygen already present in the body, or with the oxygen brought from the outside, to form "metabolic water." The amount of this water depends upon the rate of metabolism. Roughly, 200 to 500 ml of water are produced in this way every 24 hours.

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Water leaves the body through evaporation and excretion Dis regarding the trivial amount in the feces and the amount lost through the lungs, the kidneys must have at least 600 to 800 ml daily to carry on their function normally Much larger quantities are employed by the heat regulatory mechanism. The evaporation of water ranges from 800 to 2000 ml in the case of adults who are not laborers. Hard work in a warm climate may necessitate the evaporation of more than five liters of water daily. Even the starving individual lying quietly in a room heated to 70° F (21 1°C) loses some 700 ml of water by evaporation. Since the oxidations going on within the body produce only about one fourth of the amount, the remainder must come from the water normally present in the body. The organism gives up this water reluctantly, and the two mechanisms whose functions are dependent upon it compete with each other for it, as it were. The organism suffers less acutely from renal failure than from a disturbance of its temperature. A manual laborer exposed to tropical heat and unable to obtain water develops hyperthermia in a few hours, and before the day is over will probably collapse with an internal temperature of 106° F (41 1° C) or higher.

Losses of water from the body in excess of the supply, regardless of the cause (vomiting, diarrhea, diabetes, diseases associated with fever), produce an abnormal state that is called dehydration. This condition becomes serious if as much as 20 per cent of the body water is rapidly lost. Retention of body water is favored by normal secretion of thyroxine, insulin, and the lecithus. Too much water retention, called water intoxication, may also be serious unless so dium chloride is also ingested so that the electrolyte or salt concentration of body fluids is maintained constant. This is the reason why "salt tablets" are taken along with water by individuals who are doing heavy work and berspring excessively.

In health all of the water that enters the body as food and drink, and whatever arises chemically within the organism, not removed from it by evaporation, from the skin or lungs, is excreted largely in the unne, and a balance between supply and elimination is maintained. But an abnormal organism may increase its water content. The body of the sick man may contain many more liters of water than it did in its former normal state. This acquisition of extra water does not affect the outflow through vaporization. The excess of water is bound to the protoplasm and thus is incapable of passing out through the kidneys. This state in contrast to the

former one is named hydration. Clinically this is known as edema or as anasarca.

The following table shows the water exchange for a normal man busily engaged in chemical laboratory work, on a fixed diet and over a period of 72 hours.

## WATER EXCHANGE

THE EASTERNOL					
Avaslable		Excreted			
Intake (diet, water as such) . : Endogenous (oxidation less hy- drated water in body protein or fat that is set free on oxi-	5394 ml.	As urine As feces As vapor	. 1948ml, 446 . 3804		
dation)	1052		6198ml.		
The retention of water by the h	6446 ml				

#### The retention of water by the body was 6440 - 6198 = 246 m

# Water Needs:

The life of the body's organism is not only dependent upon the presence of water, but also upon the proper dilution of substances in solution. For instance, it is well known that the absence of water causes such great concentration of compounds in the tissues and fluids of the body that thirst develops, and eventually leads to pathological disturbances or fatal consequences if not relieved by an intake of water. The desire for water at any time is to bring about a restoration of the normal amount of water required by the body. This will generally amount to two quarts per day and the larger part of this water comes from the foods eaten The retention and reabsorption of water seem to be associated with a hormone secreted by the posterior lobe of the pituitary gland Experiment has shown that injury to this portion of the pituitary gland does not allow retention of sufficient water in the tissues or normal reabsorption after filtration through the kidney. Such a condition is prevalent in diabetes insipidus when abnormal volumes of water are voided daily, and large quantities are drunk to satisfy the everpresent thirst of the patient.

Proper dilution of the body's content is of special importance in accelerating salivary, gastric, and intestinal digestion, for, after all, digestion is mainly hydrolysis. From this alone it appears that the drinking of water during meals is a good thing. According to Hawk,

"the drinking of a reasonable volume of water with meals will promote the secretion and activity of the digestive juices, and the digestion and absorption of the ingested food, and will retard the growth of intestinal bacteria and lessen the extent of the putrefying processes in the intestine" Cold or hot beverages produce only a momentary change in stomach temperature

#### SELF-TESTING QUESTIONS

- 54 What are the mechanisms for the elimination of water from the body?
- 55 How is the body temperature kept normal?
- 56 What two functions of the body regulate the amount of water leaving the body?
- 57 What does an increased water content in an animal organism depend upon?
- 58 What causes a desire for water?
- 59 What amount of water is normally required per day?
- 60 Drinking water with meals performs what functions?

#### SUGGESTED ACTIVITIES

- I THOUGHT PROVOKING QUESTIONS
  - 1 How is a basel metabolism measurement of practical value in estimating the food needs of the body?
  - 2 What disadvantage would a purely vegetable dist have for a person in normal health?
  - 3 Under what conditions may sugar be found in the urine?
  - 4 Since both carbohydrates and proteins can be changed to fats in the body why are fats an essential part of the diet?
  - 5 What is meant by a positive and negative nitrogen balance?
  - 6 Is the use of an rodide in common table salt beneficial? Explain
  - 7 In what way would basal metabolism measurements be of practical value in large institutions? Explain
  - 8 What is your opinion of the value of drinking water which contains sulfur compounds as a supply of sulfur for body needs?
  - 9 What factors should be considered for rapid loss of excess weight?
  - 10 Why is gotter more prevalent in inland cities than in seacoast cities? Explain
  - 11 Are iron compounds in mineral waters valuable for good health?
  - 12 What happens to the nitrogen content of the amino acids in the process of metabolism?
  - 13 Why is it that only infants develop rickets?
  - 14 How would you expect the BMR to be affected by fevers? by certain druss?

#### II VOCABULARY TESTING OF NEW TERMS

metabolism carbohydrate tolerance transamination basal metabolic rate threshold point glycolysis

catabolism renal diabetes ornithine cycle
anabolism ketogenic tricarboxylic acid cycle

deamination antiketogenic mitrogen balance

#### III TOPICS FOR ORAL OR WRITTEN REPORTS

- I Variability in the Metabolism of Women
- 2 Influence of Food on Metabolism Specific Dynamic Action
- 3 Physical Regulation of Heat in the Body
- 4 Hormones in Metabolism

#### LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on page 756

#### CHAPTER YYII

#### HORMONES

#### CHAPTER OUTLINE

- I. GENERAL FUNCTIONS OF THE HORMONES
- II THE HORMONE OF THE PANCREAS
  - (a) Insum
    (b) The chemical nature of insulin
    (c) The role of insulin in carbohy-
  - drate metabolism
- III, THYROID AND PARATHYROIDS
  (a) The thyroid hormone
  (b) The parathyroid hormone
- IV. HORMONES OF THE ADRENAL
  - GLANDS
    (a) Epinephrine, the hormone of VII
    the adrenal medulla
    - (b) Hormones of the adrenal cortex
  - V. THE ENDOCRINE ACTIVITY OF THE GONADS
    - (a) The testicular hormone

- (b) The female sex cycle
- (c) The estrogens
  (d) The corpus luteum hormone
- VI THE PITUITARY GLAND AND
  - (a) The growth hormone
  - (b) Gonadotropic hormones of the anterior nitutary
  - (c) The lactogenic hormone
  - (d) The thyrotropic hormone (e) The adrenocorticotropic
  - hormone (ACTH)

    (f) The diabetogenic hormone
  - (g) The posterior pituitary
  - THE GASTROINTESTINAL
  - Hormones
  - (a) Gastrin (b) Secretin
  - (c) Cholecystokının
  - (d) Enterogastrone
  - (e) Enterocrima

# I. GENERAL FUNCTIONS OF THE HORMONES

It has been pointed out in previous chapters that certain glands of the body produce external secretions which are carried away from the glands by means of ducts. Examples of this type include the salivary glands, the pancreas, and the liver. There are, in addition to this type of gland, others which do not possess ducts but whose secretions appear to be carried to other parts of the body by the blood stream. These latter glands are known as the ductless glands or the glands of internal secretion. They are also called endocrine organs (Fig. 1). The active chemical compounds that are produced by the endocrine organs are known as hormones. These substances act as chemical messengers and regulate processes of a varied character throughout the body. All activities within the body are under the control of either the nervous system or hormones or a combination of the two.

Dysfunctions of the endocrine glands which result in excessive or inadequate quantities of hormones within the body produce severe diseases. To be able to understand the medical and nursing problems that result from endocrine disturbances, it is necessary to have a thorough knowledge of the chemistry and physiology of the hormones. The hormones will be discussed with regard to the endocrine organs which are responsible for their formation.

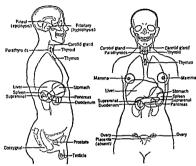


Fig. 1—Endocrine Organs. Diagrammatic chart showing the location of the various endocrine organs.

## II. THE HORMONE OF THE PANCREAS

# Insulin:

The pancreas is an organ of both external and internal secretion. The external secretion is the pancreatic juice, which plays an important role in digestion. The pancreas is also responsible for the formation of insulin, a hormone which is necessary for the proper metabolism of carbohydrates. Removal of the pancreas from an experimental animal produces a condition essentially identical with diabetes mellitus, characterized by increased blood sugar concentrations, glycosuria, acidosis, and eventually coma and death. In 1921, Banting and Best successfully prepared an extract of the pancreas which, when administered to a diabetic animal, reversed the signs and symptoms of the disease. The active principle of this extract was given the name insulin since evidence indicated that

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it was derived from that portion of the pancreas known as the islands of Langerhans. Since the discovery of this hormone much has been learned of its chemistry and physiological action

#### Chemical Nature of Insulin

Insulm is a protein which has been prepared in crystalline form All of the insulin used in the treatment of human diabetes is obtained by extraction from pancreas and its production is a by product of the meat industry. From all the evidence available, it appears that insulin prepared from the pancreas of different animals is chemically identical. Because of its protein character, insulin cannot be administered by mouth since the protein would be hydrolyzed by the enzymes of the gastrointestinal secretions. There are no satisfactory chemical methods for the determination of insulin, so that measurements must be conducted by hological assay. A unit of insulin is defined as one third that quantity which when administered to a rabbit, will produce convulsions due to excessive lowering of the blood sugar. Pure crystalline insulin has an activity of 22 units per milligram.

# Role of Insulin in Carbohydrate Metabolism

Although insulin plays a vital role in carbohydrate metabolism. the exact mechanism of its action is not vet understood. In the absence of adequate amounts of insulin glycogen is not stored in the liver, excess quantities of glucose accumulate in the blood considerable amounts of this sugar are excreted in the urine and the oxidation of glucose in the muscles is at least partially inhibited In addition the deranged metabolism of glucose causes a simul taneous disturbance of fat metabolism manifested principally by excessive production of ketone bodies Two of these ketone bodies are acidic compounds that cause acidosis Many of the symptoms of diabetic come can be related directly to this acidosis Adminis tration of adequate quantities of insulin to a diabetic patient decreases the blood sugar eliminates glycosuria promotes storage of liver glycogen and restores normal carbohydrate oxidation in the muscle With the return of carbohydrate metabolism to normal the excessive ketone body formation disappears Administration of too much insulin to a diabetic causes the blood sugar to be low ered to a level that is not compatible with normal function of the brain and as a result a shock like state accompanied by convulsions follows This condition is called insulin shock. The appearance of

a patient who is in a diabetic coma due to an inadequacy of insulin is many times quite similar to that of a patient suffering from insulin shock. Obviously it is very important to be able to distinguish between these two states. This can be readily accomplished by a determination of the blood sugar, a low blood sugar concentration (hypoglycemia) indicates that the patient is in a state of insulin shock, whereas an elevated blood sugar concentration (hypeglycemia) indicates diabetic coma. Administration of insulin in quantities sufficient to produce insulin shock often has a beneficial effect on certain mental disorders such as schizophrema or dementia praecox.

Originally it was believed that all cases of diabetes were due to madequate production of insulin by the pancreas However, it has been observed in experimental animals that the removal of the anterior pituitary gland will relieve the symptoms of diabetes in an animal suffering from this disease as a result of the removal of the pancreas. Also it has been noted that the administration of extracts of the anterior pituitary gland will produce symptoms of diabetes in a normal animal with an intact pancreas. This has led to the concept that there is a hormone produced by the anterior pituitary gland which antagonizes insulin and that a diabetic state may result from an imbalance of these two hormones, either a deficiency of insulin or an excess of the diabetogenic hormone of the anterior pituitary gland Recently, patients with carcinoma of the pancreas have had practically the whole organ removed surgically The diabetes that develops in such patients is not as severe as that observed in many diabetics

# Insulin Derivatives

Since insulin cannot be given by mouth, it must be administered by injections—usually hypodermically. The frequency of administration and the quantity given depend upon the severity of the diabetic state. In most cases, however, with normal insulin, several injections are required each day since the insulin is quickly absorbed from the site of injection, manifests its effect rapidly, and within a relatively short time apparently disappears. Two derivatives have been prepared which are sufficiently slowly absorbed from the site of injection so that only one injection per day is required. Not only is this of much less inconvenience to the patient, but also it makes available to the body a steadier, more even supply of insulin throughout the 24 hour interval. One of these compounds (protaining aims insulin, zinc, and a

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basic protein known as protamine, the other (globin insulin) is a combination of insulin and the protein portion of hemoglobin which is called globin

It has been noted that the mjection of an organic compound, alloxan, produces a selective destruction of the cells within the pancreas which synthesize insulin. This drug affords a convenient means of producing experimental diabetes which is very necessary for a better understanding of this disease. It should be recognized that although insulin provides an adequate treatment for diabetes, it does not cure the condition and practically nothing is known re garding the cause of diabetes in man. At the present time there is no evidence that alloxan is an etiological agent in human diabetes even though its chemical structure is closely related to certain important compounds within the body.

#### SELF-TESTING QUESTIONS

- 1 How can experimental diabetes be produced in an animal?
- 2 What is the chemical nature of insulin?
- 3 What are the advantages of protamine insulin or globin insulin?
- 4 What effect does the administration of insulin have on blood sugar?
  5 How can insulin shock be distinguished from diabetic coma?
- o mon can mount should be assumed and an anothe come.

# III. THYROID AND PARATHYROIDS

# The Thyroid Hormone

The thyroid gland is a small organ located in the lower part of the neck and consists of lobes on either side of the trachea An insight into the action of this gland can readily be obtained by observing the disturbances of normal body activity that result from dysfunction of this organ. It has been demonstrated that the action of the thyroid is mediated through a hormone which it produces An outstanding characteristic of the thyroid hormone is that it contains relatively large quantities of the element iodine. Kendall first succeeded in isolating an active principle from the thyroid gland and found it to be an iodine containing amino acid which was called thyroxine. The chemical structure of thyroxine is indicated below.

Thyroxine possesses all of the physiological and pharmacological activity that can be attributed to thyroid substance. A second iodine-containing amino acid, diiodotyrosine, has been isolated from the thyroid gland but it is not biologically active. There is evidence to indicate that within the body thyroxine is conjugated as a part of a protein molecule called thyroglobulin, and in reality thyroglobulin is the true hormone of the thyroid gland. However, it appears that when thyroxine is administered it is readily con-

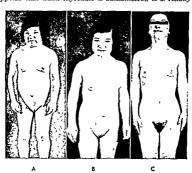


Fig. 2—Crein, age eighteen. Irregularly and Inadequately treated, onet in Intancy; no polpoble thyroid; presumably congenital athyreosis. A, before institution of adequate therapy. B, after three months of treatment, C, after one year of treatment. Hursthal, L. M, and Musulin, N.: Am J. Med 156 (July) 1946.

verted into thyroglobulin with the result that thyroxine and thyroglobulin have essentially the same physiological and pharmacological effects. In the treatment of hypothyroid states, where it is desirable to supply additional thyroid hormone to the body, pure thyroxine may be either supplied by mouth or injected, or whole dried thyroid gland may be ingested by mouth.

One of the principal activities of the thyroid gland is the regulation of the basal metabolism of the body. One might consider the body composed of a tremendous number of cells each of which could be compared to a tiny motor which is continuously using fuel and producing heat regardless of whether any actual work is being done. This "idling" activity of the body cells is the basal metabolism. The rate of idling speed of each tiny motor is dependent upon the amount of thyroid hormone circulating in the body. An excess of the hormone causes the motor to race, whereas a diminished amount results in a reduction of the idling speed or basal metabolism. Dysfunction of the thyroid may manifest itself by either an increase or a decrease in the output of the thyroid hormone. One of the most convenient means of determining hypoor hyperthyroid states is the measurement of the basal metabolism which is usually expressed as a plus or minus percentage of the deviation from normal. For instance, a figure for hazal metabolic rate of -32 means that the metabolism is 32 per cent less than normal, which would be indicative of a hypothyroid state; and a figure of +65 means that the metabolism is 65 per cent greater than normal and indicates a state of hyperthyroidism. Most authorities grant a 20 to 30 point range as normal.

Inadequacy of thyroid hormone in a growing child results in a retardation of mental and physical development. This condition is called cretinism and the patient is referred to as a cretin. Fig. 2



Fig 3—Myxedema This severe form of hypothyroidism in adults is characterized by coarse hair, decreased activity (mental and physical). How can this condition be benefited? Courfery, Dr. R. A. Shipley

shows a typical cretin both before and after treatment with thyroid hormone. If thyroid madequacy develops in an adult, a
characteristic puffiness of the skin results. This condition is spoken
of as myxedema and can be relieved by the administration of
either thyroxine or desiccated thyroid (Fig. 3). Simple goiter is an
enlargement of the thyroid gland that occurs in growing children
as a result of madequate intake of podine. Shides where ordine



Fig. 4.—Adenomas of the Thyrod and the removed specimens. Notce the huge advanced growth of the human and the week cond in on the patient who d on have sufficient strength to survive long after the operation. What would have happened if this patient had seen a competent surgeon earlier in the stage of that disease? Evaluate In veryth than bits (Sevaland Oho

was added to drinking water or to table salt have indicated that simple gotter can be eliminated by sufficient iodine intake. All though simple gotter in itself does not appear to be a serious condition, certain evidence suggests that subsequent severe thyroid disorders are more likely to occur in persons with simple gotter (Fig. 4). Acute restriction of iodine intake during growth may result in cretinism.

Hyperthyroidism occurs in patients suffering from Graves' disease which is also called exophthalmic goiter. This term arises from the fact that such patients have exophthalmos, a protrusion of the eyeballs. In such cases the basal metabolism is increased from 30 per cent to 100 per cent above normal. Formerly, conventional treatment involved the removal of a portion of the thyroid (partial thyroidectomy). A series of drugs has been discovered which selectively decrease thyroid activity and thus provide a medical means for the control of exophthalmic goiter. The most extensively used of these drugs is propyl thouracil. This compound is a sulfur derivative of the pyrimidines, a type of compound found in the nucleoproteins of the body. The administration of propyl thiouracil causes a decrease in the basal metabolism to normal, exophthalmos may disappear, and the general condition of the patient is markedly improved. Two other chemical compounds with a comparable effect on thyroid activity are thiourea and thiouracil. Excessive administration of any of these drugs will produce a hypothyroid state.

Treatment of hyperthyroidism is also carried out by administration of radioactive iodine. In thyrotoxic patients who have not recently received iodine, 50 to 90 per cent of the radioactive maternal is taken up by the thyroid gland and the rest is rapidly excreted. The radiation emanating from the radioactive iodine depresses the activity of the thyroid.

# The Parathyroid Hormone

The parathyroids are four tiny glands which are usually im bedded in the thyroid tissue. Complete removal of these glands leads to deficiency symptoms and subsequent death. Evidence has been obtained to show that these glands elaborate a hormone which plays an important role in the regulation of the calcium concentration in the serum. With an excess of the hormone, serum calcium is elevated to as much as twice the normal level of 10 mg/ 100 ml, and with inadequate quantities of the hormone the serum calcium may fall to one half the normal concentration

Extracts of the parathyroid glands have been made which con tain the parathyroid hormone. The active principle is called para thormone or parathyrin. It possesses the properties of a protein and has not been successfully isolated as a pure compound.

Dysfunction of the parathyroids may manifest itself either by increased production of the hormone or by inadequate output Most commonly, hyperparathyroidism results from adenoma or hyperplasia This brings about a mobilization of bone calcium and a thinning of the skeleton. The serum calcium level is increased and there is also an elevated urmary calcium excretion. Very fre quently, some of the excess serum calcium is deposited in the kidney, causing a chronic nephritis and renal failure. Treatment for hyperparathyroidism entails surgical removal of a portion of the enlarged parathyroid tissue. Hypoparathyroidism may arise from accidental removal of the parathyroids during thyroidectomy In this condition, the serim colourn level is decreased and a state of tetany results This is due to the fact that the calcium concen tration of the body fluid has an important regulating action on the urntability of the neuromuscular system. With madequate cal cium, the irritability increases and tonic spasms of single muscles occur, or occasionally there may be generalized convulsions should be noted that tetany may also result from marked lowering of the serum calcium because of nutritional deficiency of calcium This condition is often observed in infants and is spoken of as spasmophilia Hypoparathyroid tetany can be controlled by the administration of parathormone Temporary relief can also be obtained by the administration of large quantities of calcium salts It has been found that certain irradiated ergosterols, particularly the substance called dihydrotachysterol have an action similar to parathyroid hormone and increase serum calcium levels

#### SELF-TESTING QUESTIONS

- 6 What type of compound is thyroxiae?
- 7 What element is present in thyroxine that does not occur in most or game compounds?
- 8 What disease results from excessive secretion of thyroid hormone?
- 9 What is myxedema?
- 10 What is cretimism?
- 11 What is the relation of basal metabolism to thyroid activity?

- 12 What nutritional deficiency causes simple goiter?
- 13 What is the action of propyl thiouracil?
- 14 What is the chemical nature of the parathyroid hormone?
- 15 What effect does the parathyroid hormone have on serum calcium concentration?

#### IV. HORMONES OF THE ADRENAL GLANDS

The two adrenal glands, which are sometimes called the suprarenal glands, are situated one at the top of each kidney. Examina tion of the histological structure of these glands indicates that there are two distinct parts which are called the medulla and the cortex. Actually these two portions of the glands have an entirely different embryological origin and a distinct independent function. The medulla, or inner part of the gland, arises from the sympa thetic nervous system and produces a hormone (epinephrine) which has a specific effect on the nerve endings of the sympathetic system. The outer part of the adrenal is called the cortex and is of an epithelial embryological origin. The cortex produces a series of steroid hormones which play an important role in regulating a number of body functions which will be discussed.

# Epinephrine, the Hormone of the Adrenal Medulla

This hormone was first isolated in 1901 and has since been chemically identified and synthesized. Its chemical structure is shown below and it will be seen that it has a structure which bears a resemblance to the amino acid, tyrosine

There has been a considerable amount of misunderstanding among physiologists regarding the contribution that the adrenal medulla makes to the economy of the organism For instance, it

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is possible to remove the adrenal medulla without any detrimental effects However, this does not prove that this portion of the gland has no function One group of investigators headed by Cannon has provided evidence to indicate that the principal activity of the adrenal medulla is to enable the body to cope with emergen cies more readily. Under these circumstances, nervous stimulation of the medulla causes epinephrine to be liberated into the blood stream. The presence of this hormone in the blood results in a dilatation of the bronchioles, an increase in blood pressure, an in crease in blood sugar because of the conversion of liver glycogen into glucose which is picked up by the blood, and a decrease in blood coagulation time. Thus in times of stress more oxygen is provided for the blood and tissues (bronchiolar dilatation), more fuel is available for metabolic reactions (increased blood sugar), a better supply of blood is afforded to the tissues (increased blood pressure), and the tendency to bleed as a result of mury is de creased (shortened coagulation time)

Epmephrine has a powerful vasoconstrictor action and for this reason it is used rather extensively in medicine and dentistry to accomplish reduced blood flow in localized areas of the body. For instance, where a local anesthetic is being employed, the anesthetic effect is prolonged by the addition of epimephrine to the injected solution. This causes a reduced blood flow to the area and the anesthetic is not as readily carried away by the blood stream Similarly, it is possible to decrease bleeding, such as might occur after the extraction of a tooth by the local injection of epimephrine which constricts the blood vessels and abolishes the hemorrhage Epimephrine given by injection is also useful in the treatment of asthma by reason of its ability to dilate the broncholes. Epimephrine is likewise employed to resuscitate the heart in cases where the heart has stopped beating. In this instance, it is injected directly into the heart muscle.

#### Harmones of the Adrenal Cortex

The adrenal cortex has a much more vital function than does the adrenal medulla, since the removal of this portion of the gland from most animals results in death in a very short time. Similarly, diseases which affect the adrenal cortex are of a very grave nature and unless properly treated are fatal. It has been found that if extracts of the adrenal cortex are administered to adrenal ectomized animals, they can be maintained in good condition. The extracts

of the adrenal cortex supply hormones which are normally provided by the gland. The nature of the functions which are regulated by the adrenal cortical hormones can best be appreciated by considering the disturbances that occur in adrenalectomized animals or patients suffering from adrenal cortical insufficiency (Addison's disease). The chief symptoms in such animals or patients are:

- (1) A disturbance of water and electrolyte balance which manifests itself by dehydration, a concentrating of the blood, a decrease in the sodium content of the serum and an increase of the potassium content.
- (2) A disturbance of carbohydrate metabolism which is manifested by a hypoglycemia (lowered blood sugar) and a decrease in liver glycogen
- (3) A decrease in kidney function which results in the accumulation of urea and other waste products in the blood.
- (4) A generalized muscular weakness and a lessened resistance to cold and shock, and other stress reactions
- (5) In patients with Addison's disease there is also a bronzing of the skin which gives such patients a characteristic appearance.

Chemical study of adrenal cortical extracts has resulted in the isolation of several steroid compounds. These all possess the cyclopentanophenanthrene nucleus and differ only in the groups that are substituted on this polycyclic structure. The chemical formulas of cortisone and corticosterone, two of the most active of these compounds, are shown here.\*

CH-OH

<sup>\*</sup> In complex structural formulas of this type the hexagon is not an aromatic (henzem ring) configuration, unless the alternate double and angle bonds are shown. It is understood that where lines meet a carbon atom is present, with sufficient attached hydrogens to make it tetravalent. Note that cortisone has no gromatic charged.

Cortisone has recently been synthesized and is at present widely used in treating a variety of diseases. Corticosterone is a very active adrenal hormone but is not at present available for medical use. A third steroid called desoxycorticosterone has never been recognized as a chemical component of the adrenal gland but has been synthesized in the chemical laboratory and has a definite effect in regulating or influencing body functions that are under the control of the adrenal cortex. Cortisone primarily influences carbon hydrate fat and protein metabolism and gives either man or an mals a remarkable ability to cope with stress reactions. It has a lesser effect in regulating water and electrolyte balance but thus function is markedly influenced by desoxycorticosterone.

During the past few years, with the increase in knowledge of the function of the adrenal cortex and with the synthesis of cortisone and desoxyocrticosterone the outlook of a patient with Addison's disease has markedly improved. The simple expedient of restricting the intake of potassium and increasing the intake of sodium chloride is of immense value to the general condition of such patients. It is also possible to implant pellets of desoxyocrticosterone under the skin. These very slowly dissolve over a period of several months and afford a constant supply of the factor which regulates water and electrolyte balance. Cortisone may be administered to over come the effects of any stress reactions (e.g., infections) which may be encountered.

Cortisone also induces prompt remission of acute signs and symptoms of theumatoid arthritis, including swelling, local redness and tenderness. It has been used with success in all of the other so called collagen group of diseases (which includes disseminated

lupus erythematosus, pernartentus nodosa, dermatomyosuts and scleroderma) The compound is a potent metabolic agent whose administration must be carefully controlled Continued administration produces disturbances in carbohydrate metabolism and development of Cushing's syndrome (See Fig 9, p 568) Effects comparable to those obtained with cortisone can be obtained by the administration of the adrenocorticotropic hormone (ACTH) of the anterior pituitary This hormone is also widely used in medical practice ACTH acts on the adrenal gland and stimulates the gland to release cortisone and other adrenal cortical hormones. With an intact adrenal cortex, the action of cortisone and ACTH are comparable. In the absence of a functional adrenal cortex, ACTH has little effect.

The adrenal cortex also exerts an effect on sex Tumors of the adrenal cortex in women result in an "adrenal vurhism" which manifests itself by the development of secondary male sex characteristics including growth of a beard, lowering of the pitch of the voice, and a repression of female sex characteristics. Tumors of the adrenal cortex in males result in a less well defined syndrome. In some instances there is an increase in male characteristics, whereas in other cases, there may be a tendency toward feminization with genital atrophy, enlargement of the breasts, and an elevation of the pitch of the voice

#### SELE-TESTING OUESTIONS

16 Describe the action of epinephrine

- 17 Why is epinephrine useful as a local hemostatic agent?

  18 What are the effects of disease or removal of the adrenal cortex?
- 10 What are the enects of disease of removal of the adrenal cortex
- 19 What is corticosterone?
- 20 What is desoxycorticosterone?

### V THE ENDOCRINE ACTIVITY OF THE GONADS

The gonads (testicles or ovaries) have two types of activity One of these is the formation of spermatozoa or ova and the other, the production of hormones The nature and function of these hormones will be discussed in detail in the following paragraphs

### The Testicular Hormone

The testes elaborate a type of hormone which regulates a num ber of body functions in the male. It is responsible for the descent of the testicles the development of the accessory reproductive organs (epididymis, vas, prostate, seminal vesicles, and penis), the 556 Biochemistry

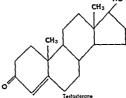
maintenance of spermatogenesis, the development of secondary male characteristics (male voice, male pattern of facial and body haur distribution, male type of skeletal muscular development), and it stimulates libido. Since there are several compounds which possess male hormone activity, they are collectively referred to as the androgens



Fig. 5.—The influence of the administration of testoste one propionate to 24 day old with te legitiom chicks. Note the tremendous stimulation of the comb caused by the androgen c harmone. Courtery Dr. Rolph 1 Dorfleon

The androgens can be assayed by injecting them into a capon (castrated rooster) and measuring the amount of comb growth produced. This is possible since the comb growth in the rooster is controlled by male hormone and in the capon there is very little comb growth.

Chemically the androgens are all of a steroid nature. The most potent of them is testosterone which can be obtained from the testis by extraction with a lipid solvent. This compound is believed to be the true physiological male sex hormone. Its structure is shown below.



A second androgen (androsterone) is present in male urine. It has a structure similar to testosterone but the physiological activities considerably less as measured by comb growth assays in capons (Fig. 5) or as indicated by clinical effects when administered to eunuchs. Testosterone has a definite clinical usefulness in cases where the testes are absent or hypofunctional. Eunuchs, for instance, have a feminine type of body build, slight growth of facial hair, a high-pitched voice, and no sexual urge. Administration of testosterone produces marked changes in body contours, growth of a beard, a lowering of the voice to the male range, an acquirement of sexual desire, and an increase in vigor and sense of well being.

### The Female Sex Cycle:

There are two important types of female sex hormones, both of which originate in the ovaries. These hormones are responsible for the development of secondary female sex characteristics, and also regulate the menstrual cycle and play an important role in pregnancy.

The action of the female sex hormones can better be understood following a brief description of the female reproductive system 558 Biochemistry

which includes the ovaries, the oviducts, the uterus, the vagina, and external genitalia. The ovaries are small bean shaped bodies which are responsible for the production of female egg cells (ova) At periodic intervals, an ovim is discharged into the oviduct (fallopian tube) and passes from there into the uterus If, as a tresult of sexual intercourse, spermatozoa are present in the uterus, the ovum may be fertilized, if this takes place, the fertilized ovum becomes implanted in the wall of the uterus and develops into an embryo During the period from puberty to the menopause the ovaries and uterus undergo continuous complex changes Present in the outer wall of the ovary are large numbers of immature graafian follicles containing ova During each menstrual cycle, one of these follicles enlarges and secretes increased quantities of estrogens, one of the two groups of female sex hormones. Ap proximately on the 14th day of each menstrual cycle in the human, the enlarged follicle reaches maturity and discharges an ovum At the point where the follicle ruptures, the cells undergo a change (lutenization) and the resulting structure is called the corpus luteum. This corpus luteum is responsible for the production of progestational hormones, the second of the two groups of female sex hormones If pregnancy does not occur, the corpus luteum undergoes atrophy approximately at the time of menstruation, undergoes atrophy approximately at the time of measuration, whereas, if the ovum is fertilized, the corpus luteum persists throughout pregnancy During the time the granfian folicide in the ovary is developing, the endometrium (the liming of the uterus) undergoes proliferation, which may be thought of as a type of de velopment rendering the endometrium capable of receiving a fer tilized ovum If the ovum is not fertilized, the endometrium under goes further changes and at the time of menstruation, the inside surface of the endometrium sloughs off leaving many exposed blood vessels which account for the menstrual bleeding. In most animals, menstruction does not occur and the female is receptive to sexual intercourse only at certain periods

### The Estragens

There are several substances of similar chemical nature which have a specific physiological action and these substances are collectively referred to as the estrogens. They are produced by the ovaries as a result of pituitary stimulation, circulate in the blood, may be metabolized or chemically altered, and are excreted in the urine. The following formulae show the structures of the three most important estrogens.

It is believed that estradiol, which is the most potent of the three compounds, is the true hormone and that estrone and estrol are products of the metabolism of estradiol. Estradiol is produced by the follicle cells of the ovary and is secreted in increased amounts during the maturation of a granfian follicle. This increased amount of estrogen causes the development of the endometrium following menstruction and produces a type of structure which makes the uterine wall receptive to the implantation of a fertilized ovum Estrogens also are responsible for the development or accentuation of secondary female sex characteristics (body contour, hair distribution, development of genitalia, etc.) In most animals, they induce estruis which is the period of "heat" in which the female is recentive to sexual intercourse.

During recent years, estrogens have been extensively employed in the clinical treatment of ovarian insufficiency. They are also useful in the alleviation of severe menopausal symptoms that sometimes occur in middle aged women. A group of synthetic organic compounds which have estrogenic activity has also been developed for the same purpose. The principal one of these substances is diethylstilbestrol. These synthetic compounds are much less expensive than natural estrogens and have the added advantage that they can be administered or ally whereas most natural estrogen preparations must be innected.

### The Corpus Luteum Hormone:

The hormone of the corpus luteum (progesterone) has been solated as a pure chemical compound and its chemical structure determined

It will be seen that it possesses the basic steroid nucleus but close scrutiny indicates that there are differences between the estrogens, and progesterone. The second substance pictured is pregnanediol which is the metabolized product of progesterone Pregnanediol is excreted in the urine and the quantity present is an indication of the activity of the corrows lutum.

The chief function of progesterone is to cause a type of growth of the endometrium which prepares it for implantation of the fertuized ovum If conception does not occur, the corpus luteum atrophies and ceases to supply progesterone and this results in a breakdown of the progestational endometrium of the uterus with subsequent hemorrhage of non clotting blood, i. e, menstruation If conception does take place, the corpus luteum persists because of the influence of prolactin (a pituitary hormone), and progesterone maintains the endometrium

#### SELF-TESTING QUESTIONS

- 21 What is an androgen? Name two androgens
- 22 At what time during the menstrual cycle is conception most likely to occur? Why?
- 23 What is the endometrium?
- 24 What is a graafian follicle?
- 25 What is the corpus luteum?
- 26 What effects do estrogens have in the female?
  27 What is the action of progesterone?
- 28 Name three estrogens

#### VI. THE PITUITARY GLAND AND ITS HORMONES

The pituitary gland (hypophysis) is a small structure situated at the base of the brain and has frequently been referred to as the "master endocrine organ" because it controls or influences several of the other endocrine structures as well as regulates many other body processes. Anatomically, the pituitary is divided into three portions. (1) the anterior pituitary, (2) the posterior pituitary, and (3) the pars intermedia or the intermediate portion. Much more has been learned of the function of the anterior pituitary than of the other two portions. Knowledge of the hormoal function of the pituitary has been acquired as a result of the following

types of animal experimentation: (1) noting the physiological effects of removal of the gland; (2) observing the ameliorative effects resulting from nnjection of extracts of the pituitary into animals with this gland removed; (3) witnessing the results produced in normal animals by the injections of extracts of the gland.

Removal of the whole pituitary or merely the anterior portion produces the following effects:

- Cessation of growth.
- Atrophy and loss of function of the gonads (ovaries and testes).
- 3. Atrophy of the thyroid gland.
- 4. Cessation of lactation in a lactating animal.
- 5. Atrophy of the adrenal cortex.
- 6. Improvement in the condition of a diabetic animal.

All of these phenomena can be reversed by the injection of extracts of the anterior pituitary glands obtained from other animals. More exacting studies and the chemical separation and purification of the crude extracts have indicated that there are several

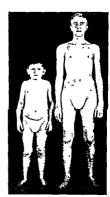


Fig 6—Hypopitularism Comparison of dwarf of 17 years with a normal youth of the same age What are the main functions of the pituitary? Courtesy, Dr. R. A. Shipley

rather than one single hormone secreted by the anterior pituitary. Six of these hormones have been obtained as relatively pure chemical compounds during the past ten years and all of these are of a protein nature. In that proteins are such complex compounds, none of the pituitary hormones has been synthesized in the laboratory. As a result, all of the pituitary hormones that are used therapeutically must be obtained from natural sources. For this reason, such preparations are very expensive.

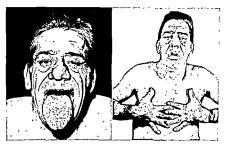


Fig. 7—Acromegaly. The disease is characterized by progressive enlargement of the bones in the face, hands, and feet, and large tangue. Overactivity of the anterior lobe of the pluttary gland in childhood produces what condition? Courtery, Dr. R. A., Shipley.

#### The Growth Hormone:

The cessation of growth in animals with their pituitary removed' as well as the increase in growth of normal animals when given pituitary extracts, has provided evidence for a growth hormone. There is also clinical evidence for a growth hormone based on the observation of patients with pituitary disorders. For instance, if the pituitary is hypofunctional during growth, a "pituitary dwarf" will result (Fig. 6). Excessive production of growth hormone also is observed in patients who have a certain type of tumor of the anterior pituitary. If excessive secretion of the hormone occurs

during childhood, proportional body growth is stimulated and a "pituitary giant" results. The giants observed in circus sideshows are usually examples of this type of pituitary disorder. However, if the stimulation occurs after closure of the epiphyses of certain long bones, a disproportionate growth pattern is observed and such individuals grow in a grotesque manner. This condition is referred to as acromesaly (Fig. 7).

## Gonadotropic Hormones of the Anterior Pituitary:

The pituitary is responsible for the development and maintenance of function of the gonads. Hypofunction of the gland results in decreased gonadal activity; and removal of the pituitary causes a loss of sexual function. Administration of pituitary extracts to immature animals produces precocious sexual maturity. Careful study of this gonadotropic activity has indicated that there are two gonadotropic hormones and these have been chemically separated and prepared as relatively pure compounds. Their action is quite different in the male and in the female. Several names have been applied to these two hormones and this has made their cognizance quite complex; but an understanding of their function is quite important.

THE FOLLICLE-STIMULATING HORMONE (FSH, GAMETOGENIC HORMONE, PROLAN A): In the female, this hormone stimulates the growth of graafian follicles in the ovary. As was discussed in the section on female hormones, the growth and maturation of a follicle are an important phase of the female sexual cycle. In the absence of the hormone, follicles do not develop and as a result, the estrogens which they produce are not available for action on the endometrium of the uterus. In the male, FSH stimulates the spermforming tissues of the testes which might be considered analogous to the ovurn-producing follicles of the ovary.

THE LUTEINIZING HORMONE (LH, INTERSTITIAL CELL-STIMULAT-ING HORMONE, PROLAN B): In the female, this hormone causes luteinization of the ruptured graafian follicle and this results in a corpus luteum. It has already been pointed out that the corpus luteum also produces an important hormone. In the male, luteinizing hormone stimulates the interstitial cells of the testes which are responsible for the production of the male sex hormone testosterone.

The relationship of the pituitary gonadotropic hormones and the female sex hormones to the menstrual cycle can be visualized

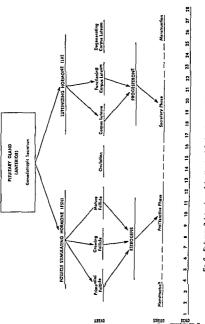


Fig 8-Endocrine Relationships of the Menstrual Cycle. Courtesy, Helen Murray.

in Figure 8. During the first phase of the cycle, there is a predominant secretion of follicle-stimulating hormone by the anterior pituitary. This causes the development and maturation of a graafian follicle. The maturing follicle in turn secretes estrogens which cause the endometrium of the uterus to develop and also produce estrus in animals. With evulation, which occurs approximately at the 14th day of the cycle, the pituitary secretes a predominant quantity of luteinizing hormone that stimulates the development of the corpus luteum. The corpus luteum produces the hormone progesterone which maintains the endometrium in a condition favorable for reception of the fertilized ovum. Towards the end of the cycle, the output of luteinizing hormone by the pituitary diminishes and the corpus luteum in turn atrophies and ceases to supply progesterone. In the absence of progesterone, the uterine wall is no longer maintained and with its degradation, menstruation occurs. In case of conception, the corpus luteum is maintained by the stimulating effect of prolactin, another anterior pituitary hormone which will be discussed later.

A substance similar to pituitary gonadotropins and called chorionic gonadotropin is produced by the placenta and appears in the urine in relatively large quantities soon after the beginning of pregnancy. The presence of large amounts of this chorionic gonadotropin is the basis for the Aschheim-Zondek and the Friedman tests for pregnancy. The injection of pregnancy urine containing this gonadotropin into immature female mice (A-Z test) or into unmated female rabbits (Friedman test) results in the rapid development and rupture of a graafian follicle within a period of 1 to 4 days. The results of such tests can be determined by macroscopic observation of the ovary. The male frog is also being employed as a test animal for the demonstration of chorionic gonadotropin in urine (i e., for a pregnancy test). Injection of urine containing chorionic gonadotropin into the dorsal lymph sac of the male frog causes the appearance of spermatozoa in the frog's urine within one or two hours. Sperm can readily be seen by examining the frog's urine on a slide under a microscope.

### The Lactogenic Hormone of the Anterior Pituitary (Prolactin):

The process of lactation subsequent to parturition is under the control of a hormone of the anterior pituitary which is called prolactin. This hormone was the first of the pituitary hormones obtained as a pure chemical compound and has been found to be a protein with a molecular weight of approximately 25 000. The hormone alone is not capable of causing lactation but functions in the breast that has been hypertrophied by estrogens. The combined administration of estrogens and prolactin will produce lactation even in the male species. There appears to be some in hibitor to prolactin that is present during the course of pregnancy but following delivery the restraining factor is removed and the secretion of milk occurs. This inhibitor substance is believed to originate in the placenta. Prolactin also is responsible for the maintenance of the corpus luteum during pregnancy.

## The Thyrotropic Hormone (Thyrotrophin)

The activity of the thyroid gland is under the regulation of a thyrotropic hormone which is secreted by the anterior pituitary Removal of the pituitary results in a decreased thyroid function and injection of the hormone stimulates the thyroid and may produce evidences of hyperthyroidism. This hormone has been iso lated and identified as a protein. It appears likely that certain thyroid dysfunctions seen in clinical practice can be attributed to an abnormality of thyrotrophin secretion by the anterior pituitary

### The Adrenocorticotropic Hormone (ACTH)

The adrenal cortex is under the control of a hormone secreted by the anterior pituitary. This hormone is called the adrenocortico tropic hormone or ACTH. In the absence of the stimulating effect of ACTH the adrenal cortex will atrophy and evidences of adrenal cortical insufficiency will appear. Much has been learned in recent years of the effect of ACTH and the adrenal cortex in overcoming stresses such as poisoning by chemicals or bacterial toxins bleeding crushing injuries burns and exposure to severe cold. When such a stress develops the pituitary is stimulated and it releases increased quantities of ACTH. The ACTH in the circulating blood in turn causes release of cortisone and other adrenal cortical hormones. These provide the protection against the stress.

ACTH is a low molecular weight protein which is prepared from animal pituitaries in much the same way that insulin is prepared from animal princreases. ACTH is non antigenic and is widely used in medical practice. The biologically active portion of the ACTH molecule has recently been synthesized (p. 401). Its uses are quite comparable to those of cortisone which was discussed in an earlier section.

# The Diabetogenic Hormone of the Anterior Pituitary

In the discussion of insulin, it was mentioned that the adminis tration of extracts of the anterior pituitary would produce disturbances of carbohydrate metabolism similar to those noted in diabetes. It has also been observed that an animal having diabetes as a result of the removal of the pancreas will be beneficially af fected by removal of the anterior pituitary gland. This has led to the belief that the anterior pituitary may secrete a hormone which antagonizes insulin In other words, this hormone tends to produce diabetes whereas insulin tends to prevent diabetes. Accordingly, this hormone has been called the diabetogenic hormone. At the present time, this hormone has not been purified and the exact mechanism of its action is not clearly defined. It is quite possible that the effect is due to the action of the growth hormone and the adrenocorticotropic hormone However, it seems that normal car bohydrate metabolism is brought about by a proper ratio of insulin and diabetogenic hormone. If there is an excess of diabetogenic hormone or a deficiency of insulin, a diabetic state will result, whereas, if the pendulum swings the other way and there is either an excess of insulin or a deficiency of diabetogenic hormone, a state of hypoglycemia will result with ultimate "insulin shock"

Since the anterior pituitary is responsible for the elaboration of many hormones, it can be readily understood that disorders of the pituitary might result in complex disease states due to an imbalance of the various hormones. One such example of this is Cushing's syndrome (Fig. 9) which is caused by an adenoma (tumor) of a certain type of cell in the gland. In this condition there is formed an excess of the adrence retortoor borrooms and the gonadatronic

hormones

## The Posterior Putuitary:

The posterior portion of the pituitary is smaller than the an terior part and because of its anatomical position, it is virtually impossible to remove it without injury to the anterior pituitary. This has made the study of the normal function of the posterior pituitary extremely difficult. There is some evidence that damage to this portion of the gland results in polyuma (increased urne output). This suggests that the posterior pituitary screetes a hormone that regulates urnary volume. There is a clinical condition known as diabetes inspidus which is characterized by an excessive thirst and the excretion of very large urns volumes.



Fig. 9—Cushing's Disease. Notice obesity of the face and neck as the result of a pituitary tumor. Tumors of what other glands may cause this disease? Courtery, University Hospitals, Cleveland, Ohio.

Additional evidence for the secretion of an antidiuretic hormone is furnished by the fact that extracts of the posterior pituitary will reduce urine volumes to normal when administered to such patients.

Chemical fractionation of posterior pituitary extracts has resulted in the separation of two fractions which have been called vaso-pressin (Pitressin) and oxytocin (Pitocin). Whether these substances are true hormones or merely compounds with specific pharmacological actions is a matter of debate at the present time. Vasopressin will increase blood pressure and has been used to combat the low blood pressure of shock following severe injury or extensive surgical procedures. It also possesses the principle which decreases urinary output in diabetes insipidus. Oxytocin has a powerful stimulating action on the contraction of the smooth muscles of the uterus. This property is made use of in certain cases encountered in obstetrical practice.

No known endocrine function is ascribed to the intermediate portion of pituitary (pars intermedia) in mammals.

#### SELF-TESTING QUESTIONS

- 29 What methods have been successfully employed to demonstrate the endocrine activity of the pituitary?
  - Name five effects that may be produced by removal of the anterior pituitary.

31 Name three clinical conditions that are due to excess or deficiency of growth hormone

- 32 Briefly discuss the role of folicie stimulating hormone (FSH) luternizing hormone (LH) estrogens and progesterone in the menstrual cycle
- 33 What are vasopressin and oxytocin? Indicate one use each might have in medical practice
- 34 What is the chemical nature of the anterior pituitary hormones?
- 35 What is the basis for the male frog pregnancy test?

#### VII THE GASTROINTESTINAL HORMONES

The fact that hormones play an important role in digestion has already been pointed out in a previous chapter. However, these relationships will be briefly reviewed. When there is no food in the alimentary canal the digestive apparatus is relatively quiescent but following the ingestion of a meal the whole system actively functions in a beautifully synchronized manner. This is due to both nervous and humoral (hormonal) control.

#### Gastrin

When food enters the stomach a hormone is released from the pyloric region which is absorbed into the blood. This hormone is called gastrin. Its presence stimulates both muscular contractions and secretory activity on the part of the stomach. Thus it produces a flow of gastric juice containing increased quantities of hydrochloric acid and pepsin. The chemical nature of the hormone gastrin is a matter of some dispute. There is some evidence that the hormone is a simple chemical substance identical with the amino acid derivative histamine. It is known that histamine has a powerful stimulating effect on gastric activity. However there is also some evidence to suggest that gastrin is a protein like hormone.

### Secretin

This is one of the hormones which is released when food enters the duodenum 't stimulates the production and flow of pancreatic juice. It is of considerable historical interest that secretin was the first recognized hormone it was discovered in 1902. Secretin has been isolated as a pure chemical compound and has been identified as a polypeptide.

### Cholecystokinin

This is a third gastrointestinal hormone. It is liberated into the blood stream when food enters the duodenum. When blood containing the hormone passes through the walls of the gallbladder it causes the muscles to contract and concentrated gallbladder.

bile is forced through the ducts into the duodenum. Thus far the hormone has not been obtained in a purified state

#### Enferogastrone:

In the process of digestion, one of the functions of the stomach is to act as a reservoir which stores the ingested food until it can be digested and absorbed. This is necessary since the intestine can handle only small quantities of food at a time. It has been found that the emptying of the stomach is controlled by a hormone (enterogastrone) which originates in the lining of the small intestine. When food enters the small intestine, this hormone is released into the blood and on reaching the stomach it temporarily inhibits further gastric secretory activity by emptying of gastric contents into the duodenum. Enterogastrone has not been prepared as a pure compound. A somewhat related substance called urogastrone with a similar physiological effect can be obtained from turne. This material has been used to treat neptic pler.

### Enterocrinin (Enterin):

This hormone also originates in the mucose of the small intestine and is released when food enters the duodenum. Its physiological effect is to stimulate secretion of intestinal juice (succus entericus). At the present time, enterocrinin has been obtained only in crude extracts

#### SELF-TESTING QUESTIONS

- 36 What was the first hormone discovered? When did this occur?
- 37, What is the action of enterogastrone?
- 38 What hormone stimulates the evacuation of the gallbladder?
- 39 Where does secretin originate? What is its action?
- 40 What is gastrin?

#### SUGGESTED ACTIVITIES

- I THOUGHT PROVOKING QUESTIONS
  - 1 Why must insulin be injected rather than given orally?
    - 2 What effect would the administration of thyrotropic hormone have on the basal metabolism of a normal individual?
    - 3 What laboratory chemical examinations are useful in the diagnosis of parathyroid disorders?
    - 4 Describe the treatment of a patient with Addison's disease 5 Suggest how hormones might be employed to produce menstrua-
    - 5 Suggest how hormones might be employed to produce mensionation in a castrated female
      6 How would you distinguish between a cretin dwarf and a pituitary
    - 6 How would you distinguish between a cretin dwarf and a pituitar dwarf?

- 7 Make a list of all the substances which are known to contain the steroid nucleus
- 8 Discuss the digestive processes indicating the relative role of hormones and enzymes
- 9 Make a list of all the diseases in which the principal disturbance is an excessive or deficient secretion of hormones 10 Name three hormones that have been prepared synthetically and
- which are useful clinically
- 11 Name the clinically useful hormone made from animal tissues

### II V

endocrine	desoxycorticosterone	thyroxine
hormone	estrogen	progesterone
ductless gland	estradiol	metakentrin
ınsulın	androgen	oxytocin
hypoglycemia	testosterone	vasopressin
hyperthyroidism	acromegaly	endometrium
adrenal medulla	myxedema	ovulation
epinephrine	cretinism	gastrın
hypoparathyroidism	thylakentrin	enterogastrone
Addison's disease	thyroglobulin	secretin
ACTH	thyrotropic hormone	anterior pituitary
graafian follicle	cholecystokinin	prolactin
cortisone	chorionic gonadotropin	enterin

#### III TOPICS FOR ORAL OR WRITTEN REPORTS

- 1 Prepare a report based on outside reading on one of the following subjects (a) Plant hormones (b) Antihormones (c) Commer cial production of insulin (d) Commercial production of thy roxine (e) The use of estrogens in the treatment of prostatic carcinoma (f) Stress reactions in disease
- 2 Present a clinical history and description of a patient on your ward suffering from some endocrine disturbance
- 3 Consult the book published by the American Medical Association 1954 Glandular Physiology and Therapy and prepare a re port based on one of the topics discussed in this text as suggested by your instructor

#### LABORATORY CHEMISTRY

Time and facilities make it impractical to carry out any laboratory experi ments on the hormones

#### CHAPTER XXIII

#### VITAMINS AND MILK

### CHAPTER OUTLINE

V. VITAMIN D

VI VITAMIN E

VII VITAMIN K

IX MILK

(b) Sources

(a) Functions and deficiency

effects

VIII VITAMINS IN NUTRITION

(b) Composition (c) Modified milk

(d) Pasteurization (e) Lactic acid milk (f) Fuel value

(a) As a food

(c) Assay and unitage (d) Requirements

- I. INTRODUCTORY DISCUSSION
  - (a) Vitamins and hormones (b) Vitamin complexes
  - (c) Vitamin assay
  - (d) Vitamin unitage
- II VITAMIN A
  - (a) Deficiency effects
  - (b) Properties (c) Sources

  - (d) Assay and unitage (e) Requirements
- III VITAMIN B COMPLEX
- (a) Thumme (Bt)
- (b) Riboflavin (Ba)
  - (c) Niacin (nicotinamide)
  - (d) Pyridoxine (Ba)
  - (e) Pantothenic acid
  - (f) B12
- IV VITAMIN C
  - (a) Functions and deficiency effects

  - (d) Requirements
  - (c) Assay and unitage
  - (b) Sources
- (g) Protein content (h) Mineral content (i) Vitamin content

# I. INTRODUCTORY DISCUSSION

During the early years of the present century it was found that a diet consisting of pure carbohydrates, fats, and proteins, together with the necessary minerals and water, was not an adequate one. Animals fed on such a purified diet did not show proper growth. and failed in health. The addition of small quantities of natural foods, such as butter and milk, usually corrected such conditions and health and growth became normal These natural foods were thought, therefore, to contain certain factors essential to correct nutrition.

Some of the first experiments in this phase of nutrition were conducted by Funk, a Polish chemist. Funk succeeded in extracting from rice polishings a substance which was highly effective in combating a disease known as beriberi, which is contracted through faulty diet. His analysis indicated that this substance was an amine, and inasmuch as it appeared to be essential to life he coined the name "vitamine" This word has since been changed to "vitamin," and it is now applied to a series of substances which are essential to proper nutrition without regard to the chemical structures of the substances

The study of vitamins has become an extremely important development in the field of foods and nutrition. It is now known that a number of diseases which were prevalent in the past were due to a lack of certain vitamins or "food accessories" Scurvy, beriberi, and rickets are typical examples of the deficiency diseases, and as such they can be corrected by proper dietary treatment.

### Vitamins and Hormones

In a number of respects the vitamins are similar to the body hormones Thus, like the hormones they exhibit specific activities are effective in small amounts and in general are essential for the proper growth and health of the body. In fact, the term "food hormones" was at one time proposed for vitamins. However, it must be kept in mind that the vitamins are supplied normally in foods, whereas the hormones are synthesized in the body itself Certain B vitamins, and vitamin K, are synthesized to a limited extent in the intestines by bacterial activity on food residues Studies have proven that vitamins hormones and body enzymes operate in close association to control metabolism.

### Vitamin Complexes

The number of vitamins has grown rapidly in recent years until at the present time some twenty to twenty five accessory food factors are recognized. Undoubtedly more will be discovered. In some cases what at first was considered to be a single vitamin has proven under further investigation to be a complex consisting of a number of individuals, each possessing specific activities. For il lustration, the original vitamin B is now known to be a complex of some eight or ten different factors. The correct terminology, therefore, is vitamins B, or the vitamin B complex. Members of a complex are often best known by their chemical names, for example, thamme hydrochloride and riboflavin are two members of the B complex.

One of the earliest classifications of vitamins was made on the basis of solubility in water and in fats. This classification con tinues to have ment, and vitamins are characterized as water soluble or fat soluble.

### Vitamin Assay:

The rat has been widely used to determine the vitamin content of foods and the potency of vitamin preparations, and to study the symptoms arising from dietary deficiencies. Rats in most instances react as do humans to variations and deficiencies in the diet. One noteworthy exception occurs in the case of vitamin C; rats require little or none, and for this reason they are not suitable animals for investigating this factor. In this connection the guinea pig has proven valuable as a substitute for the rat.



Fig 1—Rats Used in Diet Deficiency Tests. Rats are used in biological assays to determine vitamin strength. Why are rats used in preference to most other animals? Courtery, National Oil Products Co

When animals are used in the study of a specific dietary deficiency a control group is given a diet which is adequate in all respects, while a similar experimental group is provided with a diet adequate in all respects except one—it is lacking in the single factor or vitamin to be studied. All animals are weighed at regular periods, and conditions such as health, appearance of skin and hair, activity, appetite, sex response, etc. are carefully noted. In time those on the experimental diet lose weight and develop characteristic symptoms which can be attributed to the absence of the vitamin (avitaminosis).

The use of experimental animals for the determination of vitamin content and the study of deficiency symptoms usually gives excellent results Unfortunately such biological methods are time consuming, several weeks must clapse before conclusive data are available Gradually, as the chemical structures and reactions of the vitamins are revealed, chemical methods of testing for potency become feasible. The vitamin C content of a food, for example can now be determined rapidly and with considerable accuracy by methods of quantitative analysis. This is possible because vitamin C is a pure chemical substance known as I ascorbic acid, and as such it exhibits a characteristic chemical behavior. It must be emphasized that the biological methods of assay which employ experimental animals are today very important and widely used. The newer analytical methods of chemistry are not displacing but rather supplementing, the older approach.

## Vitamin Unitage

Various methods are in use for expressing the vitamin content of foods and diets in specific units of measurement. The procedures used for determining vitamin potency have been varied for this and other reasons considerable confusion has arisen in vitamin unitage. As the chemical structures of the vitamins become known it is desirable to express the quantities and requirements in terms of weight of pure substance. Several examples may be helpful here. At one time the unit of vitamin C was defined as 'that amount which, when fed as a daily allowance, just suffices to afford full protection from scurvy in a standard guinea pig.'' A more accurate unit is the International unit (I U), this is defined as 0.05 milligram (mg) of pure crystalline l ascorbic acid (vitamin C). The I U is in some more recent tabulations of vitamin requirements the recommended daily allowance, when possible, is stated in milligrams or micrograms of pure substance. (1 milligram is equal to 1000 micrograms)

#### SELF-TESTING QUESTIONS

- 1 From the foregoing discussion formulate a definition for vitamins
- 2 Why were vitamins originally called vitamines? Why was the name changed?
- 3 In what respects are vitamins and body hormones similar? Wherein do they differ?

- 4 What is the meaning of a vitamin complex?
- 5 From the standpoint of solubility, what are the two main classes of
- 6 Outline the steps in the biological method of vitamin assay
- 7 What are the various systems in use for designating amounts of vita mins?

### II VITAMIN A

Vitamin A is a fat soluble factor, and is known also as the antixerophthalmia vitamin. This substance has been isolated in pure form and the chemical structure has been established. Vitamin A is a complex, high molecular weight, primary alcohol which con tains a six carbon atom ring.

Not only vitamin A, but a number of substances called its precursors are found in nature. The precursors may be termed provitamins in the animal body they are broken down to provide the active vitamin. The four recognized precursors of vitamin A are the  $\alpha$ ,  $\beta$ , and  $\gamma$  carotenes, and a carotenoid called cryp toxanthin.  $\beta$  Carotene is the most abundant of the provitamin A group, it is available commercially in an oil solution which can be employed to correct vitamin A deficiency. There is some evidence that there are two varieties of this vitamin and the designations A, and As may become necessary.

#### Deficiency Effects

As pointed out by the term "anti xerophthalmia factor," a lack or deficiency of this vitamin in the diet over a period of time results in an eye disease Xerophthalmia is apparent as dryness and scaliness of the skin and an increased susceptibility to eye infections One of the symptoms first noticed is nyctalopia or "night blindness"; thus results when there is a lag in the regeneration of the visual purple which is essential for clear, sharp vision. As a matter of fact, the degree of night blindness, or impairment of adaptation to darkness, can be used clinically as a measure of vitamin A deficiency.

Severe vitamin A deficiency leads to disturbances other than ocular. The respiratory, alimentary, and genitourinary tracts may be affected through the replacement of normal epithelial tissue with pathological tissue. In general, body resistance to various types of infection is lowered. Thus function of vitamin A has led to the use of the term "anti-infective" vitamin. However, vitamin A must not be considered as a specific remedy for colds, respiratory afflictions, and related disorders; in itself it cannot destroy disease bacteria. The vitamin is anti-infective in the sense that it aids in maintaining healthy epithelial cells and tissue; this is the body's first line of defense in resisting infection.



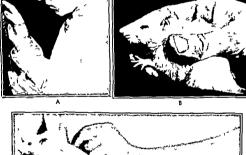
Fig 2—Vitamin A deficiency. Note "goose flesh" appearance of skin of thighs due to followiar hyperkeratitis

# Properties:

Vitamin A is insoluble in water, but soluble in fats and oils. Experiments have proven that it is fairly stable to heat, and to acids and bases. It is, however, destroyed by free oxygen and other oxidizing agents. Ordinary cooking procedures do not destroy vitamin A to any appreciable degree.

# Sources:

Vitamin A and its precursors are abundantly supplied by nature. In plants there is a correlation between greenness and yellowness of color and the vitamin A or carotene content Green leaf lettuce,



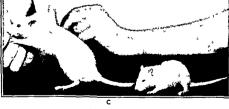


Fig 3—Vitamin A Defluency (A) A rat receiving his daily treatment (B) Typical eye infection due to lack of vitamin A. (C) Twin rats with differences in growth due to vitamin deficiencies.

cabbage, peas, and green beans are rich sources. Carrots and sweet potatoes are also excellent sources; during World War II carrot juice was prescribed for aviators to combat night blindness.

Certain foods from animal sources supply vitamin A in good amount. The fish liver oils such as cod and halbut have long been used to supply vitamin A. Butter, whole milk, and eggs are important sources. Vitamin A can be stored in the body, largely in the liver, for a considerable time.

## Assav and Unitage:

Vitamin A gives an intense blue color with antimony chloride; consequently it becomes possible to determine vitamin A content colorimetrically with this reagent. Spectrophotometric methods of assay, based upon absorption of ultraviolet light, are coming into prominence. Biological methods which employ rats are widely used despite the fact that weeks are required for collecting data.

The international unit (I.U.) of vitamin A, identical with the USP, unit, is defined as the growth promoting activity for rats of 0.6 microgram (0 0006 milligram) of standard 3-carotene.

### Requirements:

The recommended minimum daily allowance of vitamin A is generally given as 5000 I.U. for adults and children alike, with a somewhat greater quantity, about 8000 I.U., recommended for nursing and pregnant women. One to two teaspoonfuls of codliver oil will sumply this amount



Fig 4—A Deficiency Causes Infection. Illustrating a case of xerophthalmia due to lack of vitamin A A deficiency of vitamin A may produce what other Infections? Courtesy, John Anderson Thurson

#### SELF-TESTING QUESTIONS

- 8 What is a provitamin? Illustrate What other name applies to such a substance?
- 9 In what sense is vitamin A anti infective?
- 10 What is night blindness? Give the medical term for this
  11 Give at least three different ways of testing for vitamin A
- 11 Give at least three different ways of testing for Vitamin A
  12 What pure chemical substance is used as a reference in vitamin A
  - unitage? State the relationship of this substance to vitamin A

### III. VITAMIN B COMPLEX

Early in nutritional studies it was found that a substance present in rice polishings was effective in overcoming polyneurits in pigeons and beriberi in man. In the past beriberi has been a major disease in the Orient. Takaki, a Japanese naval medical officer, demon strated that beriberi could be cured and prevented by correcting the diet. The active factor which accomplishes this was given the name vitamin B. Further investigation has shown that what was at first supposed to be one factor is in reality a complex. All mem bers of this complex are water soluble. Some are essential in human nutrition, others prevent nutritional diseases in animals. The best known and likely most important members of the complex are noted here, and will be considered in order.

Thiamine (vitamin B<sub>1</sub>, thiamine hydrochloride, aneurin)
Riboflavin (vitamin B<sub>2</sub>, vitamin G)
Niacin (nicotinic acid, nicotinamide, P P factor)
Pyridoxine (vitamin B<sub>6</sub>)
Pantothenic acid (filtrate factor)
B<sub>12</sub>

### Thiamine (B<sub>1</sub>)

This important member of the vitamin B complex is known as the anti neuritic vitamin, and beriberi vitamin, aneurin, and appetite stimulating vitamin, and by the chemical name thiamine, or thiamine hydrochloride. The substance was first extracted in pure form from rice polishings, and shortly thereafter, in 1937, its chemical synthesis was announced. The structural formula for the hydrochloride is presented below. It is important to note that thiamine contains the elements N, S, and Cl, in addition to C, H, and O, and that like vitamin A it is a complex, high molecular weight, immary alcohol

FUNCTIONS AND DEFICIENCY EFFECTS: Certain names for thismine noted above suggest the nature of the pathological conditions which result when there is a deficiency of the vitamin in the diet. The disease of polyneuritis, known as beriberi in man, is specifically associated with a lack of thiamine. Polyneuritis can be produced in animals by withholding thiamine from the food. A deficiency of B1 is at first evidenced by a loss of appetite, weakness, fatigue, loss of weight, and impaired digestive processes. In more serious cases the advanced symptoms are polyneuritis (beriberi in man) and cardiovascular disturbances It has been shown that thiamine is essential for the proper functioning of the nervous system and the gastrointestinal tract. There is generally accepted evidence that thiamine is required for the proper metabolism of carbohydrates. In the absence of the vitamin the pyruvic acid which is produced in the breakdown of carbohydrates is not oxidized, but accumulates in the body and produces neu-



in the body and produces neuritic conditions.

ritic conditions.
While there are but few instances of beriberi in this country there is nevertheless little doubt but what a considerable proportion of the population suffers at one time or another from marginal thiamine deficiency. Vitamin B<sub>1</sub> cannot be stored in the body for any appreciable length of time, but must be furnished rather continuously in properly selected foods or supplementary preparations. The highly refined foods of today are

Fig 5-Vitamin B Complex Deficiency [Thinmine] Beriberi Leas





Fig 6—Vitamin B<sub>1</sub> (Th amine Chloride) Prolonged deficiency of this vitamin checks growth in young animals causes loss of appet te and results in degenerative changes in the nervous system (left). Administration of two to three International units (0.006 to 0.009 mg) of th amine chloride will cure the symptoms (right).

usually deficient in thiamine

PROPERTIES Thiamine is a water soluble factor. It is quite stable up to a temperature of 100° C in acid medium, but experimentation has shown that it is destroyed by heat in neutral or alkaline solution.

Sources The best natural sources of thiamine are the whole cereal grains, liver, lean meat, nuts, yeast, and a number of the green vegetables

Modern processes in milling grains for the production of refined flour may remove up to 90
per cent of the original thiamine 
content of the whole grain. As a 
result of decortication of grain, 
prolonged cooking processes, and 
the wasting of tooking loquors, 
the thiamine content of raw foods 
may be removed or destroyed to 
such a degree that the diet is 
deficient in this factor.

Fig 7—Girl with Beriberi as a Result of Vitam n B Deficency Why should vitam n B be included in our det? Courtesy CLINICAL PEDIATRICS Appleton Century Co



ASSAY AND UNITAGE A variety of methods have been developed for the detection and assay of thiamine. The biological rat curative method is reliable, but time consuming. The oxidation of thiamine with potassium ferricyanide produces a fluorescent compound named thiochrome, and the intensity of the fluorescence is a measure of the thiamine content. Thiamine has been found to hasten cer tain alcoholic fermentations promoted by yeast, and this affords a method of assay. In addition there are a number of colorimetric procedures.

The USP unit of vitamin B<sub>1</sub>, which is identical with the IU, is defined as the vitamin B<sub>1</sub> activity of 30 micrograms (0 003 milligram) of standard thiamine hydrochloride

REQUIREMENTS The recommended daily allowance of thiamine ranges from 700 to 900 I U, depending upon sex, age, etc. This amounts to from 1.0 to 2.0 milligrams.

## Riboflavin (B2)

Riboflavin, vitamin B<sub>2</sub>, is one of the heat stable factors of the vitamin B complex In the past it has been known as vitamin G Riboflavin has been isolated from natural sources, and its chemical structure has been proven through synthesis There are several important groups in the riboflavin molecule, among them one derived from a sugar called ribose The structure of riboflavin is given below

DEFICIENCY EFFECTS: Symptoms of insufficient riboflavin are lesions at the corners of the mouth accompanied by a characteristic reddening of the lips; the latter condition is termed cheilosis. Usually these conditions are promptly relieved by riboflavin therapy. Lesions about the eyes, keratitis, and a skin condition termed "sharkskin" can often be traced to a riboflavin deficiency.

Sources: Riboflavin is of fairly wide occurrence in natural foods; in general, sources rich in thiarnine also supply riboflavin. Lea meats, green top vegetables such as beet tops and kale, and whole grains are excellent sources. Riboflavin is stable towards heat, especially so in acid medium. Its stability is greatly decreased by alkali. Like thiamine it cannot be stored in the body for any length of time.

ASSAY AND UNITAGE: Rat curative methods continue important in riboflavin assay. Riboflavin fluoresces under ultraviolet light,

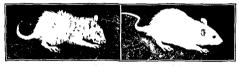


Fig. 8—Riboflavin. This part of vitamin B complex is essential to the consumption of oxygen by body cells, promotes growth, and is necessary for skin health. Rat with dematitis (left) cured by riboflavin (right).

and the intensity of such fluorescence becomes a measure of the riboflavin concentration. Recently a microbiological method has been developed which depends upon the fact that certain lactic acid bacteria require this vitamin in their production of lactic acid.

acid bacteria require this vitamin in their production of lactic acid.

No International or U.S.P. unit exists for riboflavin. Inasmuch
as the pure substance is available, requirements, etc., can be stated
in terms of milligrams.

REQUIREMENTS: It is known that riboflavin is essential to man, and to dogs, cats, rats, and chicks. The suggested daily allowance for humans is from 1.0 to 2.5 milligrams.

## Niacin (Nicotinamide):

Niacin is the most recent name for a member of the vitamin B complex which is known also as nicotinic acid, nicotinamide, and Goldberger's P-P factor (pellagra-preventive). Long before niacin

was found to function as a vitamin its structure and methods of preparation were known to chemists

FUNCTIONS AND DEFICIENCY EFFECTS NISCIN IS a specific cure for blacktongue in dogs and its analog, pellagra, in man Pellagra is a disease which prevails especially among the poorer people of southern United States who subsist on a diet which may be largely orn meal, fat pork, and molasses This disease is also known in central and southern Europe Pellagra is characterized by skin lesions, diarrhea, and mental disorders, or as Harris states, by the tree d's—dermatitis, duarrhea, and dementia People afficied with pellagra are invariably cured when fresh meat, vegetables, etc., are added to the diet. Niacin has been found as a constituent of certain coenzymes which function in cellular respiration

SOURCES The best sources of macin are the fresh organ meats such as liver, heart, and kidney, and also yeast, fish, whole wheat,



Fig. 9—N cot n.c. Ac.d. Is a Cure for Pellagra. Left hand of pellagra vict m showing the fr ghtful sk n condition which is one of the symptoms of the disease Right hand of same vict m after treatment with nicotinic acid.

milk and eggs. It is one of the most stable of the vitamins and is very little affected by heat, acid, and alkali. Very little, therefore, is lost in ordinary cooking methods except when cooking liquors are discarded.

REQUIREMENTS There is difficulty in determining with any de gree of accuracy the amount of macin needed in human nutrition The recommended daily allowance is from 4 0 to 20 0 milligrams, depending upon age, sex, activity, pregnancy, etc

# Pyridoxine (B<sub>6</sub>)

Pyridoxine, vitamin  $B_0$ , bears a structural relationship to macin, inasmuch as both are derivatives of pyridine

A deficiency of this factor in the diet of rats causes a dermatitis which is accompanied by considerable swelling and edema, especially of the paws, ears, nose, and lips. The condition is described as acrodynia, and it bears some resemblance to pellagra. Granting that pyridoxine is necessary in human nutrition, and this has not been conclusively proven, its function is not as yet established Like other better known members of the B complex, pyridoxine has been synthesized and it is available in pure form

No specific requirements have been established

## Pantothenic Acid·

A deficiency of this member of the vitamin B complex in the diet of chicks results in a dermatitis, incrustations at the corners of the mouth, and skin inflammation. When the diet is lacking in this factor young rats and certain other experimental animals show dermatitis, retarded growth, and graying of the hair. When panto themic acid is restored to the diet the grayness is replaced by the original color. This has quickened public interest in pantothemic

acid There is, however, no very positive proof that the acid pre vents graying of the hair of humans

Pantothenic Acid



Fig. 10—Pantothen c. Acid. (Filtrate Factor). Deficiency of this vitamin causes dermat t s in chickens (self). The chicken heafs rapidly following the administration of 10 mg. daily of this factor.



Fig 11—Vitamin B complex deficiency as manifested in the tongue

### RECOMMENDED DAILY DIETARY ALLOWANCES! REVISED 1963

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Designed for the maintenance of good nutrition of practically all healthy persons in the USA

(Allowances are intended for persons normally active in a temperate climate)

	Age1 Years from to	Weight kg (lbs)	Height em (in)	Cala rus	Vitamin A Value I U	Thia mine mg	Ribo- flatin mg	Niacin Equiv <sup>2</sup> mg	Asc Acid mg	Vita min D I U
Men	18-35	70 (154)	175 (69)	2900	5000*	12	17	19	70	_
	35-55	70 (154)	175 (69)	2600	5000	to	16	17	70	ı
	55-75	70 (154)	175 (69)	2200	5000	0.9	13	15	70	ı
Women	18-35	58 (128)	163 (64)	2100	5000	08	13	14	70	ı
	35~55	58 (128)	163 (64)	1900	5000	0.8	12	13	70	!
	55-75	58 (128)	163 (64)	1600	5000	0.8	12	13	70	)
	Pre	gnant (2nd	and	+ 200	+1000	+02	+03	+3	+30	400
	3rd trimester)			i l	l '	1	i .		i	
	Lac	tatung		+1000	+3000	+04	+06	+7	+30	400
Infants*	0~ I	8 (18)	I	kg x115	1500	04	0.6	6	30	400
	Į .	ļ	j.	±15		Į			,	)
Children	1 3	13 (29)	87 (34)	1300	2000	0.5	0.8	9	40	400
	3-6	18 (40)	107 (42)	1600	2500	0.6	10	11	50	400
	6-9	24 (53)	124 (49)	2100	3500	0.8	13	14	60	400
Boys	9-12	33 (72)	140 (55)	2400	4500	10	14	16	70	400
	12-15	45 (98)	156 (61)	3000	5000	12	18	20	80	400
	15-18	61 (134)	172 (68)	3400	5000	14	20	22	80	400
Guls	9-12	33 (72)	140 (55)	2200	4500	0.9	13	15	80	400
	12 15	47 (103)	158 (62)	2500	5000	10	15	17	80	400
	15-18	53 (117)	163 (64)	2300	5000	0.9	13	15	70	400
	1	1		ı	ı		1			1

<sup>&</sup>lt;sup>1</sup> The allowance levels are intended to cover individual variations among most normal persons as they live in the United States under usual environmental stresses. The recommended allowances can be attituted with a variety of common foods providing other authentia for which human requirements have been less well defined. See text for more detailed discussion of allowances and of nutrients not fabulated.

Pantothenic acid is thought to be essential in human nutrition, possibly in the utilization of other members of the vitamin B complex; it is known to be a part of coenzyme A. The substance is commercially available in the form of the calcium salt. No standards have been proposed. Natural sources of other members of the B complex usually provide pantothenic acid.

<sup>&</sup>lt;sup>2</sup> Entries on lines for sge range 18-35 years represent the 25 year age. All other entries represent allowances for the midpoint of the specified age periods i.e. line for children 1-3 is for age 2 years (24 months) etc. 3-6 is for age 41/y sets (54 months) etc.

Nacin equivalents include dietary sources of the preformed vitamin and the precursor tryptophan. 60 mg tryptophan represents 1 mg macin.

<sup>4</sup> The calone and protein allowances per by for infants are considered to decrease progressively from birth. Allowances for calcium thanning riboflavin and macin increase proportionately with calones to the maximum values shown.

<sup>\* 1000</sup> I U from preformed Vitamin A and 4000 IU from beta-carotene

## Vitamin B<sub>12</sub> (Cyanocobalamin)

This vitamin was announced in 1948 as a new member of the B complex. The compound has been isolated from commercial liver extracts as a red, crystaline, heat stable substance. It produces a positive hematological response when administered to individuals afflicted with pernicious anemias, nutritional macrocytic anemia, or sprue. Thus the physician now has at his command another agent for treating anemias. An interesting point is that chemical analysis of vitamin B<sub>12</sub> shows the presence of cobalt. Liver, milk, cheese, egy olks and meats are sources of this vitamin.

In addition to the members of the vitamin B complex just considered, a number of others are known None of these has as yet been proven essential in the human duet, but certain ones are required by animals. Some of these factors are choline, mositol, biotin, vara aminobenzoic acid, and folic acid.

#### SELF-TESTING QUESTIONS

- 13. What elements are found in vitamin B which do not appear in vitamin A?
- 14 In what manner is carbohydrate metabolism disturbed when there is a deficiency of thiamine?
- 15 State the effects of heat and pH of medium on thiamine
- 16 Are members of the vitamin B complex stored in the body? Can you advance a reason for this?
- Give the chemical names for the better known members of the vitamin B complex
- 18 Which members of the vitamin B complex are known to be essential in human nutrition? Give the deficiency symptoms of each
- 19 What is the significance of the prefix ribo- in the name ribofiavin?
  20 Is it possible to prevent gray hair in humans by the use of vitamins?
- 21. Which member of the vitamin B complex is associated with the "three d'a"?
- 22 What is cheilosis?
- 23 Why has pellagra been more prevalent in the southern states than in the northern states of the U S?
- 24 What is the objection to decortication of cereal grains? Why is it done? Duscuss

## IV. VITAMIN C

Scurvy, the disease which results from an extreme deficiency of vitamin C, has been known for hundreds of years. Berber and scurvy in all probability were the first diseases to be attributed to dietary deficiencies. In past centuries sailors on long voyages were

often deprived of fresh fruits and vegetables for weeks at a time, and as a result many were stricken with scurvy and died from its effects. Vitamin C is also known as the anti-scorbutic vitamin, cevitamic acid, and 1-ascorbic acid, the latter is the chemical name.

## Functions and Deficiency Effects:

The earlier and milder symptoms of ascorbic acid deficiency are general lassitude, soreness of gums, defective teeth, sores in the mouth, etc. These might be called symptoms of subacute or marginal deficiency. In advanced stages there is a reduction in the formation of intercellular substance, a cementing material important in capillary walls, cartilage, and teeth. As a result tissue structure is weakened, blood capillaries tend to hemorrhage, lesions appear in the bone marrow, and teeth may loosen.

It has been proven that man, monkeys, and guinea pigs require l-ascorbic acid. Other animals apparently do not require it, or possibly have the ability to synthesize it.

In point of chemical structure l-ascorbic acid is an oxidized form of a hexoes sugar. Like members of the vitamin B complex it is water-soluble factor. l-Ascorbic acid is an active reducing agent, and as such it is oxidized by loss of hydrogen to give dehydro-l-ascorbic acid. The latter, in turn, is easily reduced to l-ascorbic acid. This oxidation-reduction system of l-ascorbic acid and dehydro-l-ascorbic acid is thought to play a role in reactions which occur in the tissues.

### Sources:

Vitamin C has as its richest natural sources citrus fruits, peppers, raw cabbage, and tomatoes. Little if any is found in dry cereal

grains, meat, and eggs. Cow's milk contains on the average small quantities, with considerable variation depending upon the season of the year. This vitamin becomes especially important in the diets of bottle-fed babies since cow's milk is much poorer than breast milk in I-ascorbic acid. Added to this is the fact that heating milk to sterilize it is somewhat destructive of the vitamin. Orange juice in the infant's diet insures an adequate supply. The mursing mother should likewise be well supplied with I-ascorbic acid. Tests have proven that a substantial percentage of vitamin C is destroyed in cooking, largely the result of the fact that it is easily oxidized. As much as three-fourths of the vitamin C content of fresh vegetables may be destroyed by boiling for one-half hour.



Fig. 12—Vitamin C. Deficiency of this vitamin leads to the development of scurry, shown at the left. The disease is cured as soon as fresh vegetables and fruits are made a part of the deel (right).

### Assav and Unitage:

Guinea pigs instead of rats serve as test animals in biological assays of 1-ascorbic acid. Several methods of chemical analysis have been devised. One of these employs a dep, 2,6-dichlorophenolindophenol, for titrating the vitamin. Methods have been developed for determining the 1-ascorbic acid content of the blood and urine. All chemical methods of analysis are dependent upon the fact that 1-ascorbic acid is a reducing agent.

The I.U. and U.S.P. unit of l-ascorbic acid are identical, and may be defined as the anti-scorbutic activity of 0.05 milligram of standard l-ascorbic acid. Dietary requirements are usually stated in terms of weight of the acid.

### Requirements:

The recommended daily allowance of vitamin C varies from 30 milligrams for infants to 100 milligrams for adults. Even

greater amounts are recommended during pregnancy and nursing 1 Ascorbic acid is produced commercially and is available in various pharmaceutical preparations

#### SELF-TESTING QUESTIONS

- 25 Why were sailors especially susceptible to a vitamin C deficiency? Can you advance a reason for the practice of calling sailors limeys?
  26 Is the rat a suitable test animal for I ascorbic acid studies? Discuss
- 27 In 1 ght of the effect of heat on vitamin C how should a housewife mod fy cooking procedures?
- 28 What rather common type of diet may lead to a marginal scurvy?
- 29 How are infants and growing children protected from vitamin C deficiency? Why is this especially important for bottle fed babies?

### V VITAMIN D

Vitamin D is the factor associated with the disease known as ickets hence the term "anti rachitic" vitamin There are a number of substances called sterols which possess anti rachitic value, but only two of these warrant consideration. One is ergosterol, a provitamin which under irradiation gives vitamin  $D_2$  and the second is 7 dehydrocholesterol, also a provitamin which upon irradiation provides vitamin  $D_3$ . Vitamins  $D_2$  and  $D_3$  are very similar in chemical structure. Vitamin  $D_2$  is known as calciferof the structural formula appears below. All members of the vitamin  $D_3$  group are fat soluble.

## Functions and Deficiency Effects

A deficiency of vitamin D in children results in an affliction called rickets Improper calcification of bones characterizes this

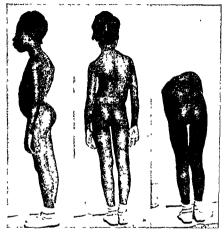


Fig. 13-Vitamin D Deficiency. Scaliosis Courtesy, Therapeutic Notes

disease. Rachitic bone structures are soft and elastic; this leads to various deformities commonly described as bowlegs, knock-knees, beaded ribs, and pigeon breast. Poor teeth and dental caries can ofttimes be traced to improper calcification arising from insufficient withmin D.

In adults a deficiency of this vitamin may disturb the calcium and phosphorus metabolism to such a degree that a softening of the bone structures becomes evident. The term osteomalacia applies to such a condition. Blood analyses on rachitic individuals show a low phosphorus but a normal calcium content. Vitamin D, therefore, is essential for the proper utilization of calcium and phosphorus, elements necessary for bone structures. Merely to provide the body with adequate supplies of minerals which contain these elements is not enough. Vitamin D must also be present for their proper metabolism.

### Sources:

Ergosterol, provitamin  $D_2$ , is found in ergot and in yeast. It is activated by exposure to ultraviolet light to give vitamin  $D_2$  or calciferol. Irradiated ergosterol is sold under the name viosterol; it provides vitamin D but not vitamin A as is sometimes erroneously supposed. 7-Dehydrocholesterol, provitamin  $D_3$ , is present in the skin, and its irradiation produces active vitamin  $D_3$ .

The best natural sources of vitamin D are the fish liver oils, of which cod liver oil is the best known. Egg yolk and butter are fair sources; however, the majority of natural foods are low or completely lacking in vitamin D.



Fig 14—Vitamin D Deficiency. Rickets. Courlesy, Therapeutic Notes

In evaluating this vitamin in human nutrition it must be recognized that bright, direct sunlight is essential for the conversion of the sterol of the skin into an active form, that foods for the most part are lacking in this vitamin and its precursors, and that it is essential for the proper utilization of calcium and phosphorus in building bone structures. Modern living conditions too often deprive us of direct sunlight, and when such is the case supplementary sources of vitamin D should be utilized. This is especially important for infants and children Some advances in overcoming vitamin D deficiency have been made by the practice of adding irradiated ergosterol to milk and certain other foods. Vitamin D is relatively stable and the usual cooking procedures and storage of foods destroy very little of it.

## Assav and Unitage:

The biological method is the one usually employed for the determination of the vitamin D content of foods. Young rats and chicks are used in the experiments. Rickets is produced in young rats by the use of a so-called rachitic diet, a type which is high in calcium, low in phosphorus, and free from vitamin D, but adequate in all other respects. Rickets appears within a few weeks. The



Fig. 15—The boy with school lunch is in decided contrast to the underprivileged boy, a victim of molnutrition. About how many calories should be provided daily for a growing boy? Courtesy, U. S. Dept of Agriculture.

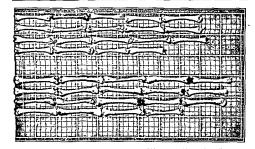


Fig 16—Chickens Are the Largest Consumers of Vitamin D. Notice the difference in bone growth of chicks fed on a control diet (upper group), and those fed with food irradiated to produce Vitamin D How does vitamin D promote growth? Courtey, du Pont Company

rachitic rat is then given the food whose vitamin D potency is to be determined, and the calcifying effect on the bones is studied. Such observations may be made by use of the x ray, or by killing the animal and studying the calcification in split sections of the bones.

Another assay procedure is the quantitative determination of the amount of bone ash in bones. Rachitic bones yield considerably less ash than normal bones.

The I.U. of vitamin D is the same as the U.S.P. unit, and is defined as the vitamin D activity of 1.0 milligram of a standard 0.01 per cent solution of irradiated ergosterol (calciferol) in olive oil. One gram of cod liver oil contains on the average 100 I.U.

## Requirements:

The recommended daily allowance for children is 400 I.U. This amount is not supplied normally in the diet. The vitamin D requirements for adults have not been established; it is undoubtedly necessary, and when not available through sunshine it should be provided up to 400 I.U. Women during pregnancy and lactation should receive between 400 and 800 I.U. as a daily allowance.

#### SELF-TESTING QUESTIONS

- 30 Why is additional vitamin D generally recommended for infants and children but not for adults?
- 31 Name the precursors of the two vitamins D considered here and state how each is activated
- 32 Outline the various symptoms of severe rickets
- 33 How does vitamin D aid in proper mineral metabolism?
- 34 Vitamin D is sometimes called the sunshine vitamin' Discus
- 35 How is the biological method of vitamin D assay conducted?
- 36 In what important analytical respect do normal and rachitic bones differ?
- 37 Why should an individual's occupation and geographical location be considered in vitamin D requirements?
- 38 Why might activated cod liver oil be preterable to viosterol for vonnesters?

# VI. VITAMIN F

Diets deficient in vitamin E produce sterility in rats. In the male rat sterility is due to degeneration of the germinal epithelium and destruction of spermatozoa. The female rat deprived of this vitamin shows normal conception and formulation of the ovum, however resorption of the fetus occurs. In addition to its part in

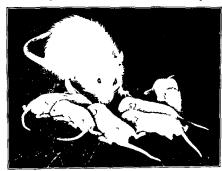


Fig 17--Vitamin E. This v tamin controls the number of bables in a litter of rats

reproduction there is evidence from work with experimental animals that a lack of vitamin E causes atrophy of the voluntary muscles. This condition is termed muscular dystrophy.

There are at least three closely related substances which exhibit vitamin E activity. These are named  $\alpha$ ,  $\beta$ , and  $\gamma$ -tocopherol. The first of these,  $\alpha$ -tocopherol, is the most potent and is now available commercially. All are fat-soluble factors.

Vitamin E has a widespread occurrence in the natural foodstuffs. Wheat-germ oil is the best known source; other vegetable oils are excellent. Green leafy vegetables and whole grains are likewise important sources. Vitamin E is highly stable toward heat, acid, and alkali, but it is susceptible to destruction through oxidation. When fats and oils become rancid through oxidation the vitamin E content suffers.

No suitable unit of vitamin E has yet been established, in fact it remains to be proven that it is essential to the reproductive processes in man. Clinical data as yet are not conclusive.

#### VII. VITAMIN K

Vitamin K is the anti-hemorrhagic factor. A deficiency of the vitamin leads to a prolonged coagulation time of the blood. As a result there is a tendency for subcutaneous hemorrhage. Prothrombin is required in the normal clotting of blood, and investigations point to the fact that vitamin K is essential for the production of prothrombin.

In cases of obstructional jaundice in man there is a lack of bile fluid, and it becomes impossible for vitamin K to be properly absorbed from the intestine. This leads to a reduction in the level of vitamin K in the bloodstream, and surgical operations may prove fatal because of hemorrhage. In such cases physicians administer vitamin K to the patient for several days prior to the operation in order to maintain a safe prothrombin level.

## DATA ON SOME VITAMINS

Names	Deficiency Symptoms	Principal Functions	Best Sources	
Vitamin A Anti zerophihalmia vitamia (β-Carotane the chief precursor) Fat-soluble	Eye infections Night blundness Relarded growth Lowered resistance to infections	Maintenance of normal infection resisting tus- sues Proper functioning of visual purple Promotes growth	Green leafy vegets bles Yellow vegetables Pash liver tills Butter	
Vitamin B: Thumme bydrochlo- ride Anti neuritic vitamin Water-soluble	Digastive disturbances Retarded growth Polyneuntus Beriberi	Stimulates appetite Promotes growth Proper metabolism of carbohydrates Normal gastric and in testinal activity	Yeast Whole cereal grains Pork Laver	
Vitamin B2 Riboflavin Vitamin G Water-soluble	Impaired growth Lamtude and weak none Frances at mouth (chedona) Glosatus	Normal growth Prevention of chellosis	Yeast Whole grains Green leafy vegeta bles Organ meats (liver etc.)	
Nicein Niceinie scid Niceinsmide Anti pellagra vitamin Water-soluble	Gastrointestinal dis- turbances Mental disturbances Blacktongue (in dogs) Pellegra	Normal functioning of gastrountestinal tract Promotes growth Prevents skin lessons Prevents pellagra	Yeast Glandular meets Fish Green leafy vegeta bles	
Vuamin B <sub>19</sub>	Antonia	Produce remasion in permicious anemia	Liver	
Vitamin C Ascorbic acul Cevitamic scid Anti-scorbutic vitamin Water-soluble	Tenderness of joints Sores in mouth Lowered resistance to infection Scurvy	Proper healing of wounds Normal growth and structure of teeth Prevention of anemia Prevention of scurvy	Catrus fruits Tomatoes Fresh cabbage perpers Pruits, vegetables	
Vitamin D  Calciferol (Da)  Activated 7-dehydro- cholesterol (Da)  Anti-rachitic vitamin  Fat-soluble	Poor assimilation of Ca and P Faulty bone structures Improper calcification Outcomalacia Rickets	Correct utilization of Ca and P in metabolam Prevents faulty tooth structure carses Prevents rickets	Irraduated ergosterol and other sterols Fish liver oils Action of sunlight Vitamin D enriched foods	
Vitamin E a Tocopherol Anti-sterility vitamin Fat-soluble	Sterility in cats Piscental failures Muscular strophy in experimental animals	Normal reproduction in rate Prevention of muscular dystrophy in rate	Wheat-germ oil Corn and cottonseed oils Croon leafy vegets blos	
Vitamin K Anti-hemorrhagic vitamin Blood coagulation vitamin Fet-eduble	Prolonged congulation time for blood Hemorrhage Azemia	Aids in production of prothrombus Normal clotting of blood	Green losfy vegeta blee Alfalfa Tomatoes	

Newborn infants often have a low prothrombin level, and if such is the case, injury at birth may lead to extensive hemorrhage. Here again the physician finds vitamin K valuable, it may be administered to the mother prior to childbirth or to the newborn baby

There are several related substances which possess vitamin K activity All are fat soluble. All are derivatives of a structure called 1,4 naphthoquinone. The general formula given here suffices for various substances of vitamin K activity. These factors differ in the nature of the radical.—R.

Vitamin K is of general occurrence in natural foods, green leafy vegetables are outstanding sources. A normal diet provides sufficient vitamin K. However, there is the possibility of faulty absorption when there is a lack of bile fluid or an obstruction of the bile duct.

Vitamin K is heat stable Its activity is diminished or completely destroyed by strong acids and bases, and by oxidizing agents Light also has a destructive action

No standards or recommended allowances have been formulated for vitamin K

### SELF-TESTING QUESTIONS

- 39 Discuss vitamin E and vitamin K requirements in human nutrition
- 40 What is the meaning of muscle dystrophy?
- 41 How is it possible for an individual to suffer from lack of vitamin K even though it is adequately supplied in the diet?
- 42 Discuss the applications of vitamin K in medicine

### VIII VITAMINS IN NUTRITION

There is no disputing the fact that the public annually spends thousands of dollars needlessly on supplementary vitamin preparations Intensive radio and television advertising and other high pressure methods have held vitamins before the general public as cures for all varieties of ills, regardless of origin

On the other hand it has been proven conclusively that a number of the vitamins are essential in human nutrition. It is true, also, that under ordinary hving conditions the normal adult is provided with sufficient quantities of the necessary vitamins if he wisely selects for himself a varied diet. Authorities agree that infants and children, even under the best dietary conditions, should be provided with supplemental sources of vitamins C and D. When living con-



Fig 18—Fruits and Vegetables Nutrition authorities insist that fruits and vegetables be generously used in the daily diet. Why is this? Courtery, National Dairy Council

ditions are not normal, as in time of war, and when individuals are deprived of an adequate varied diet because of food shortages, poverty, etc., vitamin deficiency symptoms may appear

Unfortunately, a number of our foods are highly refined Such a process, as illustrated by the decordication of wheat, removes vitamins and minerals. To remedy this particular situation enriched flour is widely used. Such flour contains added thiamine, riboflavin, macin, and iron, it is a decided improvement, but even so it does not contain all of the nutritionally valuable factors which were present in the whole grain. The enrichment of whole milk by the addition of vitamin D and of oleomargarine by the addition of vitamin A are additional examples of present day trends in the food industries.

The opinion prevails that America is well fed, yet studies have proven that at least one-third of the population is not receiving a det which is nutritionally adequate. Every individual owes it to himself to carefully study his dietary habits and assure himself that he is adequately supplied not only with the necessary quantities of carbohydrate, fat, and protein in their proper balance, but also with adequate amounts of those minerals and vitamins which have been proven essential in human nutrition.

### IX. MILK

## As a Food:

Milk is the best and most nearly perfect food, since it contains in an easily digestible and very nourishing form the three nutrients, carbohydrate, fat and protein, most, if not all of the vitamins, a balanced quantity of inorganic salts (especially calcium acid phos phate, CaHPO<sub>4</sub>) which are so necessary for the growth of tissues, strong bones and teeth, organic acids, certain nonprotein introgenous constituents, and a number of active enzymes and bacteria

Milk, however, has some deficiency, otherwise it would be con sidered a perfect food. It is a very dilute food (87 per cent water) with a low content of vitamins B, C, D, and a low content of iron, the latter element being essential to the formation of hemoglobin

Milk is amphoteric in reaction, though normally it is slightly acid (pH 6 6 to 6 9).

## Composition:

The constituents of the milks of all species are the same, but not in the same percentage, each species developing a milk particularly

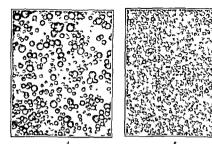


Fig. 19—Heat Changes the Size of Fat Globules in Milk. (A) shows the fat globules in bottled milk (Magnification). 1000 times for both.) What inferences can be drawn from these pictures? Courtesy Evaporated Milk Association.



Fg 20-Mik made the difference. Why sordinary cows mik not a perfect food?

adapted for the growth of its own kind. In fact, the composition varies directly with the length of the time required for the development of that species. Thus infants grow slowly and double their

weight in 180 days, cows in 47 days, cats in 9 days, and rabbits in 6 days. It follows, then, that cow's milk may be good, but not the best, milk for infants. For this brief treatise, only human, cow, goat, and mare's milk will be considered, their relative composition being shown in the following table.

Constituent	Human	Cow	Goat	Mare
Water	87 5	87 0	87 0	87 5
Carbohydrate (lactose)	60 to 75	45 to 55	4 4	6 89
Fat	20 to 40	20to50	41	1 17
Protein (casein, lactalbumin, lactoglobulin)	07to15	25 to 40	37	1 84
Ash (salts of P, Ca, Mg, K, Na, Cl, etc)	0 3 to 0 15	06to07	0.9	03

A comparison of the composition of the different milks shows that mare's milk more closely resembles human milk than does cow's milk, and consequently is an excellent substitute for mother's milk. Goat's milk is somewhat similar to cow's milk.

The lactose of milk sugar is derived from blood sugar (glucose). The fats are derived from the phospholipids of the blood and are mostly composed of palmitin and olein, with smaller amounts of stearin and myristin, and still smaller amounts of the glycerides of lower fatty acids (butyric, caproic, etc.) Other lipids presented in traces are lecithin, cholesterol. The yellow compound is lactochrome. The proteins are derived from the amino acids of the blood, and are mostly composed of casem (80 per cent), the remainder being lactalbumin and lactoglobulin. The salts and remaining constituents are also derived from the blood.

Mulk is not to be considered as fiftered fluid from the blood and casen formed in the glands, although many of its constituents (vitamins, uric acid, urea, etc.) must have dialyzed from blood plasma. After delivery and for many days the mammary glands secrete a yellowish, alkaline fluid called colostrum, which acts as a purgative on the newly born infant. Such a milk has a high content of total solids, the chief constituent of which is albumin.

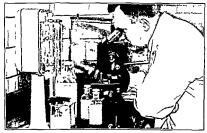


Fig. 21—A Milk Laboratory. Trained chemists and bacteriologists analyze milk to meet specified standards. What advantages has this laboratory? Courtesy, Supplee-Seafest, Philadelphia.

The composition of milk is changed somewhat by variations in diet, but the flow and yield are influenced by such factors as diet, age, nerve conditions, etc.

## Modified Milk:

Milk may be modified to resemble human milk, but it is never "just as good," From the preceding table it is evident that cow's milk is high in protein but low in sugar as compared with human milk. By diluting cow's milk and adding sugar (preferably lactose or Dertri-maltose) a satisfactory mixture of practically the same composition as human milk is obtained (Fig. 22). Too much added sugar (over 7 per cent), although fattening, may cause gas and colic and lead to serious trouble. Unless cow's milk is diluted, the high protein content may cause indigestion and colic. Too much fat also leads to various disturbances Goat's milk is somewhat richer in fat and contains slightly more salts than either human or cow's milk, and it, like cow's milk, contains less lactose than human milk. Since milk has some nutritional deficiencies it is essential that the growing infant within six or seven weeks after birth be supplied with orange or tomato juice as a vitamin C corrective, and a week or so later with cod liver oil or exposure to direct sunlight (ultraviolet light) for vitamin D deficiency. Iron deficiency will be

automatically taken care of months later when the milk diet is being supplemented with egg concoctions and purees of green vegetables. A recent practice is the addition of minerals and vitamins to provide a fortified milk

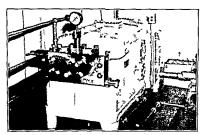


Fig 22—Homogenia no Machine Since in Ikis somewhat mad fed by the ration of the row many milk concerns are meeting the demands of physic ans for mad fled milks such as vitam in lik lodated in Iki, soft curd in Iki, homogenized milk etc. How may the vitam a content of a milk differ in the winter from that in the summer? Courtery Supples Scaltast Philadelphia

### Pasteurization

Since cow's milk is liable to become contaminated with the different pathogenic bacteria which produce tuberculosis, typhoid fever, dysentery, and other serious diseases, milk is pasteurized Pasteurization is a process of heating milk to 63° C, for 30 minutes, then quickly cooling it, and protecting it from contact with the air (Fig 23) Milk so treated is free from all disease producing organ isms and is just as digestible and nutritious as raw milk, but it has a slightly different taste because of formation of a volatile sulfide (probably H-S) from partly decomposed proteins, and contains less than half the antiscorbutic vitamin C normally present Since vitamin C in raw milk is not present in sufficient quantities, it follows that this is not such a serious loss. The deficiency of vitamin C, as mentioned, may be provided for by orange or tomato juice

Since pasteurization destroys some of the vitamin potency of milk, health authorities have allowed raw milk to be sold under

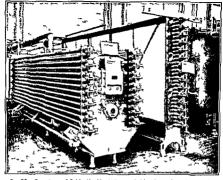


Fig. 23—Guard ons of Public Health. Milk. ninckell ned vots is pastey ized by heating with hot water at 63° C. for 30 minutes. There without contact with air it is quickly cooled in as eless of pear. What is the advantage of the reliat vely low temperature upon plotens plessell in the milk? Courtery Bowman Pary Co.

certain restriction as certified milk. Such a milk is produced from disease free cows the milk being handled under rigid sanitary con ditions, and when sold must not show a count over 10 000 bacteria per ml

### Lactic Acid Milk

Upon standing, milk sours and curdles as the result of lactic and fermentation of the lactose present

At pH 47 its isoelectric point the casein precipitates and the milk is said to curdle. The curdling of milk may also be brought about by the addition of rennin in the form of rennet as obtained from the lining of calves' stomachs. The rennin changes soluble calcium casenate into insoluble calcium paracaseinate. In precipitating casem by either acids or rennin, some fat and traces of
other constituents are removed from the milk. Such a mixture is
used to make cheese the flavor and kind depending upon the type
of organism present during the fermenting or injening process. The
liquid surrounding the curd is known as whey. Lactic acid milk,
such as buttermilk and acidophilus milk is considered much more
digestible than untreated milk. Furthermore, it is interesting to
learn that pathogenic bacteria will not grow in sour milk. So it is



Fig. 24—Mik and its Products. Which food pictured would you expect to be highest in fat content? In protein content? In water content? Courlesy of National Dairy Council

that nature comes to man's assistance in protecting milk, the most important of all our foods. Such bacteria change the intestinal flora by forming an acid medium which is unfavorable for the growth of putrefying and fermentative bacteria

#### Fuel Value

Milk is a good fuel because it contains fat and sugar. One quart of milk yields 675 Calories an amount sufficiently ample to supply

Child, 1 year old with two thirds of total calones required daily Child, 5 years old, with one half of total calones required daily Boy, 10 years old, with one third of total calones required daily Man, 21 years old, with one fourth of total calones required daily

One glass of milk yields approximately 100 Calories, which is equivalent in fuel value to any of the following

2 eggs (large)

2 slices of bread

2 potatoes (medium)

1 large serving of lean meat

From a financial standpoint, the amount of energy from a quart of milk is far in excess of that obtained from the same amount of money expended for meat and eggs. Besides being valuable as fuel to keep the body warm we must not lose sight of the fact that milk also repairs tissues, promotes growth, and builds bone



Fig 25—Economical Value of Milk Milk is almost an ideal food What prevents it from being a perfect food?

## Protein Content

It has already been mentioned that the most important difference between cow's milk and human milk is the high protein content of cow's milk. When milk enters the stomach, rennin, the gastric nuice ferment, hydrolyzes the casem (85 per cent of the protein of milk) into soluble paracasem, which combines with the calcium salts to form an insoluble curd, called paracasemate. Provided the milk is drunk slowly, the curd will be soft and in a finely divided state, in which form it can easily be digested by pepsin. Since the casem of human milk is of a still more flocculent state it should be considered more directible.

Cereal proteins are very low in lysine and tryptophan, two very important amino acids, which are absolutely essential for growth According to the findings of Rose's there are at least eight amino acids which are essential to maintain the body's growth and repair lysine, tryptophan, phenylalanine, leucine, isoleucine, threonine, methionine, and value

Foods which contain the essential amino acids are almonds, cheese, eggs, lean meat, milk and glutelin of corn. The addition of milk to cereal foods aids greatly in nutrition.

## Mineral Content:

Milk contains a well-balanced quantity of morganic salts, all that are needed in nutrition. It contains a very plentiful supply of calcium and phosphorus compounds which are needed for growing strong bones and teeth. A glance at the following illustration shows the amount of lime in various foods.

Food	Length of line gives proportional amount of lime
1 cup of milk	
1 cup of carrots	
1 egg	<del></del>
2 shces of bread	<del></del>

Although there is a low content of iron, still it is in sufficient quan tity and suitable form to supply amply the nutrition requirements

## Vitamin Content

Milk contains most, if not all of the vitamins, being especially rich in vitamin A and vitamin B<sub>2</sub>, the ones most important for normal growth and for preventing certain deficiency diseases. But for the fact that milk is low in vitamin B<sub>1</sub> (antineutric), C (antisecributic), D (antirachitic), in iron, in hemoglobin forming and reproduction forming substances, milk would be a perfect food

<sup>\*</sup>W C Rose Chem and Eng News vol 30 p 2298 1952



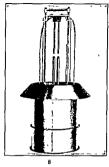


Fig. 26—Irradiating Milk with the Ultraviolet Ray. Provitamin D, naturally present in milk, is instantly converted into vitamin D, the antiradhilic vitamin, by exposing it a few seconds to the rays from an electric arc (8) on a repidly moving film, by what other means can milk be made to contain a high vitamin D content? Courters, Balle 474 onc Co

In conclusion, it is very evident that milk has practically everything needed in the diet, all the necessary substances for nutrition.
The dietary rule of a quart of milk each day for every child is
much more than a precept based on individual opinions or drawn
by analogy from the results of feeding experiments with lower animals; it now rests on scientific evidence obtained by extensive and
intensive experiments directly upon the children themselves.

As a rule, children must have one quart of milk, and adults should

As a rule, children must have one quart of milk, and adults should have one pint of milk daily.

#### SELF-TESTING QUESTIONS

- 43. What materials are present in milk that make it a desirable food?
- 44. What keeps milk from being called a perfect food?
- 45. In what two noticeable respects does human milk differ from cow's milk?
- 46 What is the function of colostrum?

- 47 How may cow's milk be modified so as to compare favorably with human milk?
- 48. Too much sugar and protein in milk may cause what trouble?
- 49 How are the nutritional deficiencies of milk supplied in infant feeding? 50 How is milk pasteurized and how does pasteurization affect its vitamin content?
  - 51 Milk may be curdled by what two substances?
  - 52 Why is buttermilk or acidophilus milk considered very digestible?
  - 53 How does milk compare with other foods as a source of energy?
- 54 What two important amino acids occur in milk, and are essential for
- 55 What compounds occurring in milk are essential for growing bones and teeth?
- 56 What are the two most important vitamins in milk, and what are their functions?

### SUGGESTED ACTIVITIES

### I THOUGHT PROVOKING QUESTIONS

- 1 Advance an explanation for the fact that the fat soluble vitamins are stored for a time in the body, while the water soluble vita mins are not
- 2 Which of the vitamins are most likely to be inadequately supplied in the diet? How can this be easily remedied?
- 3 Which vitamins are especially important in the diets of babies and children? What two items in the infant's diet will supply these?
- 4 What is the function of the so-called protective foods?
- 5 Discuss the effect of pH of medium on vitamin stability Comment on the practice of adding sods in cooking certain green vegetables to preserve the color
- 6 Cite several cases where the vitamin is known to play a direct part in metabolism
- 7 Do you feel from observations that the average citizen of this
- country enjoys an adequate diet? 8 Can you suggest a reason why macin has been substituted as a name for nicotinic acid?
- 9 What part of the sunlight is effective in activating the sterol in the skin? Why is direct exposure to sunlight necessary?
- 10 How can you account for the fact that the vitamin C content of
- milk varies considerably with the season of the year? 11 What advances have been made in the food industries to provide
- vitamins in nutrition?
- 12 Discuss milk as a source of vitamins
- 13 Why is milk called our most perfect food? Does it have any deficiencies?
- 14 How are the disadvantages of milk as a food corrected?
- 15 How do cow s milk and goat s milk differ from human milk?
- 16 How are cow's and goat a milk modified when used as food for babies?

- 17 What is the effect of the Lactobacillus acidophilus on the intestinal fore?
- 18 What factors will increase lactation? Decrease?

### II VOCABULARY TESTING OF NEW TERMS

polyneuritis anti neuritic cheilosis beriberi microgram keratitis decortication antı rachitic dystronby vitamin ergosterol precursor carotene acrodynia nyctalopia hypovitaminosis viosterol provitamin avitaminosis calciferol ribose antı xerophthalmıc irradiation anti scorbutic

- III TOPICS FOR ORAL OR WRITTEN REPORTS
  - 1 Diseases Due to Vitamin Deficiencies 2 Recommended Vitamin Allowances in the Diet
  - 3 The Use of Supplementary Vitamin Preparations
  - 4 Cows Milk in Infant Feeding

### LABORATORY CHEMISTRY

Laboratory exercises for this chapter will be found on page 766

#### REVIEW OF DEFINITIONS

### CHAPTERS XVIII THROUGH XXIII

The following terms are important in the study of chemistry. A mastery of them will help one build a scientific vocabulary that will be invaluable in future study or reading

- acetonuria (as e-to nu ri a) A condition marked by the presence of acetone and acetone bodies in the urine
- albuminuria (al bu min u re-a) Albumin in the urine
- alkaline tide An alkaline condition in the urine following meals due to the withdrawal of hydrogen ions to form the hydrochloric acid in the stomach
- amylopsin (am il op sin) The starch hydrolyzing enzyme of the pancreatic juice
- anabolism (an ab o lizm) Constructive metabolism The opposite of catabolism
- antienzyme A substance that inactivates an enzyme EXAMPLE HgCl<sub>2</sub>
- antiketogenic Substances that prevent acidosis
- anuria (an u ri a) Refers to the condition when scarcely any urine is secreted ascorbic acid (as kor'blk) Vitamin C
- avitaminosis (a vi ta min o sis) A pathological condition due to the lack of a vitamin.

#### EXAMPLE Rickets

- basal metabolism The minimum amount of energy required to maintain life when the body is at rest and without food
- bile The secretion of the liver that aids in digestion and absorption of fats in the intestine
- blood A circulating tissue existing in a closed system of tubes which branch off to every cell
- calciferol A crystalline compound that is isomeric to ergosterol and influences calcium metabolism
- carbohydrate tolerance The capacity of the body to oxidize or store glucose
- carotene (căr o ten) A yellow compound in plants from which vitamin A is synthesized by the animal organism
- casts Cylindrical formations of proteins that are discharged into the urine from the kidney tubules

catabolism Destructive metabolism Opposite of anabolism

cholesterol (kol-es ter-ol) A bile constituent which assists in fat absorption

chyluria (ki lu re-a) The presence of chyle in the urine

coenzyme Enzyme activator

condensation Reactions between like or unlike molecules with or without the

EXAMPLE Formaldehyde plus phenol to form resur

deamination (de am in a shun) A process involving the splitting off of the mitrogen of the amino group into ammonia

 $digestion\$  The breaking down of complex bodies into simple soluble ones which the body can absorb and use

enterokinase (en ter o kı'nas) An enzyme which activates trypsinogen

enzymes (en zimes) Catalysts produced in life processes

EXAMPLE Pensin

erepsin The protein hydrolyzing enzyme of the intestinal juice

ergosterol (er gos te rol). The substance which upon exposure to ultraviolet rays changes to vitamin  ${\bf D}$ 

erythrocytes (er 1th 10 sites) Red corpuscles

hematuria (hem at u re a) Blood in the urine

hemoglobinuria (hem o-glo-bin u re-a) Hemoglobin in the urine

heparin An antiprothrombin

hirudin A commercial anticoagulant extract from leeches

hormones Internal secretions of the endocrine glands which stimulate certain tissues or organs

EXAMPLE Secretion stimulates the pancreatic cells to cause a flow of pancreatic juice

inverting enzyme. The sucrose hydrolyzing enzyme in the intestinal juice irradiated. Pertaining to ultraviolet radiations of the skin or of foods.

isoagglutinins Antibodies which agglutinate the blood cells of those of the same species

ketogenic (ke-to jen ik) Substances which may produce acidosis or ketosis ketosis (ke-to sis) A condition of acidosis

leukemia (lu ke me-a) Pathological condition of the blood when it contains an abnormal number of white blood cells

leukocytes (lu'ko sites) White blood corpuscles

lymph An alkaline fluid, colorless, in the lymphatics and bathing each cell

metabolism The chemical and energy changes taking place in tissues They may be anabolic or catabolic

oliguria (ol 1g u're-a) A scanty secretion of urine

pensin. The protein hydrolyzing enzyme of the gastric juice

plasma The fluid part of blood and lymph

platelets Round, colorless discs in the blood which assist in the change of soluble fibringen into insoluble fibrin to form the blood clot

polyuria (pol e-u re-a) Excessive secretion of urine

prothrombin A zymogen which combines with the calcium salts to form throm bin, an enzyme

ptyalin (ti al in) The starch hydrolyzing enzyme of the saliva

pyuria (pi u re-a) Pus in the urine

rennin The enzyme that hydrolyzes casein of milk into paracaseinate

secretin A hormone which stimulates the pancreas

serum The clear yellow liquid left after the removal of fibrinogen from the plasma

steapsin The fat hydrolyzing enzyme of the pancreatic juice

syneresis (sin-er e-sis) A shrinkage exhibited by fibrin and other colloidal gels

threshold point. The point of concentration when glucose begins to pass from the blood into the urine

thrombin An enzyme which changes soluble fibrinogen into insoluble fibrin thrombiplastin: A factor from damaged platelets and tissue which initiates blood clotting

trypsin A protein hydrolyzing enzyme of the pancreatic Juice

urinary calculi Compact masses of insoluble mineral salts in the urinary tract

vitamins Substances that are essential for normal nutrition

zymogen The inactive state of an enzyme, a proenzyme
EXAMPLE Persinogen.

## PART IV

# APPENDIX

### SOME ADDED INFORMATION FOR REFERENCE WORK

### CONTENTS

I	Antidotes for Some Common Poisons	620
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## I ANTIDOTES FOR SOME COMMON POISONS

Name	Antidote or Treatment				
Acids (mineral)	Milk of magnesia limewater in milk soapsuds baking soda Do not use an emetic				
Alkalies (caustic)	Citrus juices vinegar buttermilk Demulcents Do not use an emetic				
Alkaloids	Strong coffee for morphine and opium otherwise strong tea				
Chloroform ether	—cold water on head and chest Artificial respiration				
Phenol	Glass of 50 per cent alcoholic liquid Remove by emetic (mustard) Epsom salts egg white milk				
Salts of heavy metals (As Cu Pb Hg Ag Zn)	Egg white milk Remove by emetic				
Unknown poison	One spoonful of two parts powdered charcoal one part magnessum oxide one part tannic acid. Keep dry until ready for use and then use one heaping teaspoonful in a glass of warm water				

## II ANTISEPTICS AND DISINFECTANTS

Antiseptics are chemicals which check the growth of bacteria, while disinfectants destroy the bacteria. This classification or division of such chemicals into antiseptics and disinfectants depends not so much upon the actual substance used as it does upon the strength of the solution. A brief consideration of some common examples is listed as follows.

## ANTISEPTICS

Used for	Chemicals	Uscs
	Bichloride of mercury (mer curic chloride)	One tablet (7½ grain) in one pint of water makes a 1 1000 solution, which is chiefly used on the hands previous to the per formance of an operation Continued use irritates the skin It is not used on sur gical instruments as it corrodes metal
Hands	Alcohol (ethyl alcohol)	A 50 to 70 per cent solution will penetrate bactera, but stronger solutions are not so active So called green soap owes its germicidal action in part to the alcohol (43 per cent) contained in it Alcohol coagulates and precipitates proteins
	Sulfur	Used as an continent to check the growth of bacteria, and to destroy parasites as in scabies
Skin	Ichthyol	It is an antiseptic in various skin diseases to relieve itching and to soften the skin
	Soapsuds	Ordinary lather destroys most germs, after thorough scrubbing and then rimsing under running water
Wounds and ulcers	Hypochlorite solutions	Dakin s solution contains 0 45 to 0 50 per cent sodium hypochlorite. Free chlorine is liberated to combine with the NH <sub>2</sub> radical of the proteins in the tissues to form chloramine which as an antiseptic is about 15 times as effective as phenol, and is not injurious to the tissues.
	Potassium per manganate	It is an oxidizing disinfectant in 1 to 3 per cent solutions for wounds and in 1 1000 to 1 5000 solutions for gargles and douches

# ANTISEPTICS (continued)

Used for	Chemicals	Uses
,	Iodoform	Mostly used in gauze soaked with a 5 to 10 per cent solution of iodoform. Not commonly used any more
Wounds and ulcers	Picric and tannic acids	Used chiefly in treatment of burns or scalds Stops bleeding
and theers	Phenyl mercuric nitrate	Effective against many skin infections. Is not possonous, destructive, or irritative to tissues or open wounds. Noncorrive to surgical instruments. Is many times more powerful than binchlonde of mer cury, Mercurochrome, or phenol
	Boric acid	A 2 to 4 per cent solution is used in eyes, nose, or other sensitive membranes with out producing any irritation
Mucous	Compound sodium borate solution (Dobell's solution)	A 1½ per cent sodium borate, phenol, sodium bicarbonate, glycerin and water solution mostly used as an alkaline gargle and as an antiseptic nasal douche
membranes	Silver nitrate	A 1 per cent solution (followed by physio logical saline solution) in the eye of the newborn to prevent genorrheal infection In stronger solutions (6 to 10 per cent) it is very destructive to the tissues
	Mild protein silver (Argyrol)	As a colloidal solution of silver and albumin it is used in 10 to 25 per cent solutions for antiseptic and astringent purposes Less irritating then silver nitrate

# DISINFECTANTS

Used for	Chemicals	Uses
Purifying air in rooms Preserving tissues	Formaldehyde (gas)	A 40 per cent solution of formaldehyde gas is called by the trade name 'formaln' A 4 per cent solution preserves tissues a 1 to 2 per cent solution disinfects instruments
	Sulfur dioxide	Formed by burning sulfur Disinfects but will bleach colored fabrics
Purifying the air and certain solutions	Chlonne	This gas in the presence of moisture is a powerful disinfectant. It is used mostly as chlorinated lime to disinfect stools and unne and also to remove odors. Used commercially to purify drinking water Oridizes bacteria directly, or combines with the amino group (NH <sub>2</sub> ) of bacterial cell to form chloriamine (NH <sub>2</sub> Cl) which kills the bacteria by oxidation
Sinks etc	Phenol (carbolic acid)	Two to five per cent solutions are fatal to all bacteria Concentrated solutions are corrosive
	Cresols	Generally prepared as emulsions or soapy solutions (common trade name of Lysol) They are more powerful than phenol
	Iodine	A 2½ to 3½ per cent solution of iodine in alcohol (or in water +KI) is used to dis infect the skin before an operation. Dis infection is due to oxidation and precipitation of protein
Skin	Merthiolate	An organic combination containing about 50 per cent mercury, and less toxic than bichlonde of mercury, used mostly in solutions of 1 1000 to 1 2000
	Metaphen	A yellow odorless powder containing about 56 per cent mercury in organic combina- tion more powerful than bichloride used on skin 1 200 and for irrigations 1 2500 to 1 10 000
Wounds	Merbromin (Mercurochrome)	Two per cent solution is used for surface wounds and infections Not very valuable

#### III. METHODS OF MEASUREMENT

#### 1 Matric Measurement Rased on Decimals

Up to the time of the French Revolution, there was much con fusion arising from the use of different standards in different local ities to measure length, volume, and weight Accordingly, a commission, appointed by National Assembly of France, devised a uniform and unchangeable standard, which was called the metric system. This system is used almost exclusively in every civilized country excepting the English speaking countries, and even there it is used for scientific measurement. Its great advantage is in being a decumal system, in which its divisions and multiples are in ratio of tens, and therefore easy to work with

The practical use of the metric system in the hospital is its employment in connection with medication and treatments, apparatus and instruments, laboratory work and metabolic work

#### METRIC UNITS OF LENGTH, VOLUME, AND WEIGHT

#### The Meter Is the Unit of Length

I meter (m.) = 10 decimeters (dm.)

1 decimeter = 10 centimeters (cm.) 1 centimeter = 10 millimeters (mm.)

1 millimeter = 100 millimeters (m 1 millimeter = 1000 microns (µ)

1 millimeter = 1000 microns (µ)
1000 meters = 1 kilometer (km)

#### The Liter Is the Unit of Volume

1 liter (l) = 1000 milliliters (ml)

Note ml is frequently written as cc (cubic centimeter)

#### The Kilogram Is the Unit of Weight (Mass)

1 kilogram (kg) = 1000 grams (Gm)

I gram ~ 1000 milligrams (mg)

Remember 1 kilogram = 1000 Gm 1 gram = 1000 mg 1 liter = 1000 ml or cc

# 2. Metric-English Conversion Factors

To Change	To	Multiply by
meter	ınch	39 37
inch	centimeter	2 54
lutex	quart, (liquid),	1.057
quart (liquid)	liter	0 946
kilograms	pound	2 205
pound	gram	453 59
gram	grain	15 432
ounce (fluid)	milliliter	29 57
ounce (avoir)	grams	28 35
gallon	liters	3 785

# 3. Apothecary System and Metric Equivalent:

#### Apothecary's System

```
60 grains (gr ) or minims (g) = 1 dram (3)
8 drams = 1 ounce (5)
12 ounces = 1 pound (lb )
or
16 ounces (fluid) = 1 pint (0)
```

# Metric-Apothecary Equivalent (Approximately)

I gram = 15 gr	I ounce = 30 Gm	
l cubic centimeter = 吸 xv	1 fluidounce = 30 cc.	
1 fluidram = 4 cc	1 quart = 1 l.	
1 dram = 4 Gm	1 grain (% Gm) = 0 064 Gr	n

## Equivalents

Metric	Apothecary	Household	
4 cc = 4 Gm	mg 60 = gr 60 = 31	1 t = 1/3 T = 60 gtt	

# 4. Household Measures:

#### Household Measures Approximate Equivalents

60 drops (gtt )	= 1 teaspoonful (t.)	60 gtt	= 1 teaspoonful
3 teaspoonfuls	= 1 tablespoonful (T)		= 4 cc or ml.
2 tablespoonfuls	= 1 fluidounce		≈ 60 minima
6 fluidounces	= 1 cupful		= 60 grains
8 fluidounces	- 1 glassful		= 1 dram
			½ ounce

#### 5. Convenient Relations:

1 dime weighs about 25 Gm 1 ml 19 : 1 dime is about 1 mm thick

# IV. TEMPERATURES

#### 1. Temperature Scales:

The only difference between the Fahrenheit (F) or the ordinarily used thermometer in our homes and the centigrade (C) or scentifically used thermometer is the manner in which they are graduated. The temperatures at which chemically pure water freeze and boils are taken as fixed points on both scales when the barometric pressure is 760 mm Examination of the figure shows the freezing point, boiling point, and the relation between them A simple method for conversion from one to another follows:

To change Tahrenheit temperature to centigrade Add 40, multiply by 5/9, subtract 40

To change centigrade to Fahrenheit Add 40, multiply by 9/5, subtract 40

#### 2. Some Important Centigrade Temperatures:

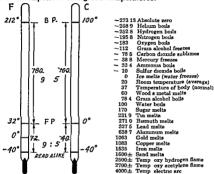


Fig 1—In the three points of equivalence
the two intervals are in the ratio of 9.5

## V. SOME QUALITATIVE TESTS

#### 1. Borax Bead Tests:

When a clear borax bead, made by fusing borax on the end of a platinum wire, is touched to a speck of certain compounds and reheated either in the oxidizing (outer) flame or in the reducing (inner) flame, the following colors are produced

Metal	Oxidizing Flame	Reducing Flame	Metal	Oxidizing Flame	Reducing Flame
Chromium Cobalt Iron	Green Blue Yellow	Green Blue Green	Manganese Nickel	Violet Brown	Colorless Colorless or turbid

#### 2. Cobalt Nitrate Tests:

When a substance is intensely heated on a charcoal block before and after being moistened with a dilute solution of cobalt nitrate, the following colors are produced

Metal	Color	
Aluminum	Blue when Al compound is infusible	
Magnesium	Pale pink a somewhat unsatisfactory test	
Zinc	Green	

# 3. Common Acid Radical Tests:

		1
To Test for	Add	Result
Bromide	Cl <sub>2</sub> water + CS <sub>2</sub>	CS2 is colored yellow to red
Carbonate	HCI	Gas, CO <sub>2</sub> , which in turn forms a white ppt (CaCO <sub>3</sub> ) with limewater
Chloride	AgNO <sub>3</sub>	White ppt AgCl, insoluble in HNO:
Iodide	Cl2 water + CS2	CS2 is colored violet
Nitrate	FeSO4 (sat) +	
	cone H2SO4	Brown ring forms
Phosphate	Ammonium molybdate solution	
	and warm	Yellow ppt insoluble in HNOs
Sulfate	BaCl <sub>2</sub>	White ppt BaSO4 insoluble in HCl or HNOs
Sulfide	HCl	Gas, H <sub>2</sub> S, which turns lead acetate paper black (PbS)
Sulfite	HCI	Gas SO <sub>2</sub> , which decolorizes KMnO <sub>4</sub> solution

# 4. Flame Tests

Compounds of the following metals held in the flame on a platinum wire show the following colors

Metal	Color	Metal	Color
Barium Calcium Copper Lithium	Yellowish green Orange red Emerald green Red (carmine)	Potassium Sodium Strontium	Violet Yellow Red (crimson)

# 5. Tests for Combustible Gases

$H_2$	Begins to burn with slight explosion and an almost invisible
	flame, water forming from the combustion may be condensed
	on a cold glass surface
co	Burns with pale blue flame to form carbon dioxide which clouds limewater
CH4	Burns with a luminous flame to form carbon dioxide and water
C.H.	Odor, burns with smoky flame, decolorizes bromine water
	Odor, burns with very sooty flame decolorizes bromine water
H <sub>2</sub> S	Odor of spoiled eggs, burns with bluish flame to form sulfur
	diamide destroys mount load sectate names

# 6. Tests for Noncombustible Gases:

HCI	Sharp pungent odor, fumes in moist air, and with ammonia forms white cloud (NH4Cl), turns most litmus paper red
SO <sub>2</sub>	Odor of burnt matches, decolorizes potassium permanganate solution
Cl <sub>2</sub>	Sharp odor, greenish yellow color bleaches moist litmus paper
CO2	Colorless and odorless forms white precipitate with limewater
NO.	Sickening odor, brown color, very soluble
N <sub>2</sub>	Reacts with hot magnesium to form a nitride which with hot water yields ammonia
NH.	Sharp penetrating odor, turns moist litmus paper blue, with hydrogen chloride forms white fumes of ammonium chloride
0,	Odorless, causes glowing splint to blaze, reacts with nitric oxide to form brown nitrogen dioxide
N20	Sweetish odor, supports combustion of glowing splint
NO	Combines with oxygen of air to form brown nitrogen dioxide
Br.	Red liquid, vaporizes easily, irritates throat.

	VI. TES	rs FOR	TEXTILE	FIBERS	
Test	Anımal	Fibers		Vegetab	e Fibers
Effect of	Wool	Sılk	Cotton	Linen	Rayon
Heat (flame)	Burns slowly Odor of bu		1	from	n when removed flame inpleasant
Base (strong) 10% NaOH	Dissolves	entirely		Not da	solved
Acid (cone ) HCl HNO:	Not affected Yellow	Dissolves Yellow	ŀ		Dissolves slowly

# THE PERIODIC ARRANGEMENT OF THE ELEMENTS ACCORDING TO ATOMIC NUMBERS VII. PERIODIC TABLE

(Atomic Weights Based on Carbon-12)

INERT VIIA ΝX ? IVA VIIIB VIIB VI B IVB

,					ļ		l		ĺ						
Lanhande Series	38 Ce 12	140 907 Pr 59	145.7 Nd 24	PH 19	150.35 Sm. 62	151 96 Eu	5G23	158 924 Tb	162 50 Dy	164 930 Ho 67	167 26 Er	168 934 Tm		174 97 Lu	
	232 038 Th	8 (231) 238.04 Pa U 91 92	238.04	2 NP 0	Pu Pu	\$ A B B	20°	7 Bk	igg s	Es 6	88 F 8	(256) Md	g Sg	18 7 8 18 7 8	

# VIII. THE CHEMICAL COMPOSITION OF SOME FOOD MATERIALS\*

	Water	Protein	Fat	Car- bohy- drate	Ash	Fuel Value per Lb
Apples	846	04	05	142	03	290
Asparagus, cooked	916	21	33	2 2	0.8	220
Bacon, smoked	20 2	10 5	64 8		51	2930
Bananas	75 3	13	0.6	220	0.8	460
Beans, baked	68 9	69	2.5	196	21	600
Beans, string, canned	93 7	11	01	38	13	95
Beefsteak, porterhouse	600	219	20 4		10	1270
Bread, white	35 6	93	12	527	12	1205
Butter	11 0	10	85 0	'	30	3605
Cabbage	91.5	16	03	56	10	145
Candy		1		960	} -	1785
Carrots	88 2	11	04	93	10	210
Celery	94.5	11	01	33	10	85
Cheese, cottage	72 0	20 9	10	43	18	510
Chicken (fowl)	63 7	193	163		iö	1045
Chocolate	59	129	48 7	303	22	2860
Consommé	960	2.5		0.4	11	55
Corn, canned	761	2.8	12	190	0.9	455
Eggs boiled	73 2	13 2	120		08	765
Halibut steak	75.4	186	5 2	1	10	565
Ham, smoked	39.8	16 5	38 8		47	1945
Lettuce	94 7	12	03	29	09	90
Macaroni, cooked	78 4	30	15	15.8	13	415
Milk, whole	870	33	40	50	07	325
Oatmeal gruel	916	12	0.4	63	0.5	155
Oleomargarine	95	12	83 0		63	3525
Olives green	580	11	276	116	17	1400
Oranges	86 9	0.8	02	116	0.5	240
Oysters	88 3	60	13	33	11	230
Peanuts	92	258	38 6	24 4	20	2560
Peas, canned	85 3	36	02	98	11	255
Potatoes, boiled	75 5	2.5	01	20 9	10	440
Potatoes, sweet, cooked	519	30	21	421	09	925
Salmon, canned	63 5	218	121		26	915
Sausage, Wieners	439	280	22 1	16	44	1485
Sauerkraut	888	17	0.5	38	52	125
Spinach, cooked	898	21	41	26	14	260
Strawberries	904	10	0.6	74	0.6	180
Tomatoes, canned	94 0	12	02	40	06	105
Walnuts, California	25	184	64 4	130	17	3300
Wheat, shredded	81	105	14	77 9	21	1700
# Compiled from Bulletin N	o 28 ff	S Depart	ment of	Lemontine.		

<sup>\*</sup> Compiled from Bulletin No 28, U S Department of Agriculture

#### IX. TABLE OF PHYSICAL CONSTANTS OF ELEMENTS\*

Element	Symbol	Valence	Atomic Number	Atomic Weight†	Density (g/ml)	Melting Point °C	Boding Point °C
Actinium	Ac	3	89	(227)		1050 0	1
Alummum	l Al	1 3	13	26 9815	2 70	660 0	2450 0
Americium	Aro	3, 4, 5, 6	95	(243)	117		l
Antimony	Sb	3.5	51	121 75	6 62	630.5	1380 0
Argon	Ar	, o	18	39 948	1 40	-1894	-1858
Arsenic	As	±3,5	33	74 922	5 72	8170	613 Ot
Astatine	At		85	(210)		(302)	
Barrum	Ba	2	56	137.34	35	7140	16400
Berkelium	Bk	3.4	97	(247)	ſ	ſ	[
Beryllium	Be	2	4	9 0122	1.85	1277 0	2770 0
Bismuth	Bı	3,5	83	208 980	98	271 3	1560 0
Boron	В.	3	5	10 811	234	(2030)	ļ
Bromme	Br	±1, 4, 5	35	79 909	3 12	~72	580
Cadmium	Cd	2	48	112 40	8 65	320 9	765 0
Calcum	Ca	2	20	40 08	1 55	838 0	14400
Californium	Cf	3	98	(251)	[	1	
Carbon .	C	2, 4	6	12 01 11	2 26	3727 0‡	48300
Cerum	Ce	3, 4	58	14012	677	804.0	34700
Cessum	Cs	1	55	132 905	190	287	690 D
Chlorine	CI	±1, 4, 5, 6, 7	17	35 453	1 56	-1010	-347
Chromium	Cr	2, 3, 6	24	51 996	7 19	1875 0	2665 0
Cobalt	Co .	2,3	27	58 933	89	14950	2900 0
Columbium	SER N						
Copper	Cu	1, 2	29	63 54	8 96	1083 0	2595 0
Curium. Dysprosium	Cm Dy	3 3	96 66	(247) 162 50	8.56	1407 D	2330 0
Einsteinium	Ea	3	99	(254)	856	14070	23300
Erhum	Er	3	68	167 26	9.15	14970	2630 0
Europium	Eu	2,3	63	151 96	5 24	826 0	1490 0
Fermum	Fm	2,0	100	(253)	0.24	0200	14500
Fluorine	F	-1	9	18 9984	1 11	-2196	-188 2
Francium	Fr	1	87	(223)		(27)	- 200 -
Gadolmum	Ga	3	64	157 25	7.87	13120	2730 0
Gallium	Ga	2 3	31	69 72	5 91	29 75	2000+150
Germanium	Ge	4	32	72 59	5 32	937 4	2830 0
Glucinum	SEE B	eryllum					
Gold .	Au	1,3	79	196 967	193	1063 0	2970 0
Hafnium	Hf	4	72	178 49	13 I	2222 0	5400 Q
Helium	He	0	2	4 0026	0 126	-2697	-268 9
Holmium	Ho	3	67	164 930	8 80	14610	2330 0
Hydrogen	H	1	1	1 00797	0 071	-259 2	-252 7
Indum	In	3	49	114 82	731	156 2	2000 0
Iodine Indium	I.	±1, 4, 5, 7	53	126 904	4 94	113 7	183 0 5300 0
Iron .	Fe	2, 3, 4, 6	77 26	192 2	22 5	2454 0	3000 0
Krypton .	Kr	2,3	36	55 847 83 80	7 86 2 6	1536 0 -157 3	-1520
Lanthanum	La	3	57	138 91	619	9200	3470 0
Lawrencium	Lw	, ,	103	100 91	1 619	3200	24100
Lead	Pb	2, 4	82	207 19	114	3274	1725 0
Lithium	Ĺ	"i"	3	6 939	0.53	1085	1330 0
Latecium	Lau	á	71	174.97	9.85	1652 0	1930 0
Magnessum	Mg	ž	12	24,312	1 74	650 0	11070
Manganese	Mn	2, 3, 4, 6, 7	25	54 938	7 43	1245 0	2150 0
·							

<sup>\*</sup> The 103 chemical elements known at the present time are included in this table. Some of those recently discovered have been obtained only as unstable isotopes.

<sup>†</sup>Based on Carbon-12 Figures enclosed in parentheses represent the mass number of the most stable isotope

<sup>‡</sup> Element sublimes unless under pressure

## IX. TABLE OF PHYSICAL CONSTANTS OF ELEMENTS\* (Continued)

Element	Symbol	Valence	Atomic Number	Atomic Weight	Dens ty	Melting Point °C	Boiling Point C.
Mendelevium	Md	1 .	101	(256)	1		1
Mercury	Hg	1 2	80	200 59	136	-38 4	3570
Molybdenum	Mo	23456	42	95 94	102	26100	6560 D
Neodymnum	Nd	3	60	144 24	700	1019 0	3170 0
Neon	Ne	, 0	10	20 183	1 20	-2486	-2460
Neptumum	Np	3 4 5 6	93	(237)	195	6370	
Nickel	N	2 3	28	58 71	89	14530	2730 0
Niobium	Nb	3 5	41	92 906	84	2415 0	3300 D
Nitrogen	N.	2 ±3 4 5	7	14 0067	0.81	~2100	-1958
Nobelmm	No		102	(254)	i		
Ozmium	On	23468	76	190 2	226	2700 0	8500 0
Oxygen	0 1	-2	8	15 9994	114	~218 B	-183.0
Palledium	Pd	2.4	46	106 4	120	15520	3980 0
Phosphorus	P I	±345	15	30 9738	1 82	44 2	280 0
Platinum	Pt	2 4	78	195 09	21.4	17690	4530 0
Plutomum	Pu	3 4 5 6	94	(242)		640 0	3235 O
Polonium	Po	2 4	84	(210)	(9.2)	2540	
Potassum	100		19	39 102	0.86	63 7	~60.0
Prascodymuum	Pr	3 4	59	140 907	677	919 0	3020 0
Promethrum	Pm	3 '	61	(147)	1	(1027)	
Protactinium	Pa	4.5	91	(231)	154	(1230)	
Radium	RA	2	88	(226)	50	700 0	l
Radon	Rn	l õ	86	(222)	4.5	(-71)	(-61.8)
Rhenium	Re	12467	75	186.2	21.0	31600	6900 D
Rhodium	Rh	2 3 4	45	102 905	124	1966 0	4500 0
Rubidom	Rb	i	37	85 47	1.53	38 9	688.0
Ruthenum	Ru	23468	14	101 07	122	2500 0	4900 0
Samarum	Sm	2 3	62	150.35	7 49	1072 0	1630 0
Scand um	6c	a	21	44.956	30	1539 0	2730 0
Selemmo	Se	-2 4 6	34	78 96	4 79	2170	685.0
Silicon	Sı	4 4	14	28 086	2.33	14100	2680 0
Silver	Ag	Ιí	47	107 870	10.5	960 8	22100
Sodium	Na	l i	11	22 9898	0 97	978	892 0
Strontum	Be	2	38	87 62	26	768 0	1380 0
Sulfue	g	-9346	16	32 064	2 07	1190	444 6
Tentalum	Te	5	73	180 948	166	2996 0	B425 0
Technetmm	Te	7	43	(99)	22.5	(2130)	
Tellurum	Te	-2 4 6	52	127 60	6.24	449.5	9898
Terburn	Th	3 4	65	158 924	8 25	13560	2530 0
Thallium	m	13	81	204.37	11 85	303 9	14570
Thornum	Th	4	90	232 038	117	17500	35500
Thulnum	Tm	l a	69	168 934	9.32	1545 0	17200
Tin	Sn	2 4	50	118 69	730	231 9	2270 0
Titanium	(T)	[ 34 ]	22	47.90	451	16680	3260 0
Tungsten	w	23456	74	183 85	193	34100	£930 D
Uranum	Üΰ	3 4 5 6	92	238 04	19 07	1132.0	3818 0
Vapadium	ν̈	2345	23	50 942	6.1	1900 0	3450 0
Xenon	Хe	0	54	131.30	3 06	-1119	-1090
Ytterbum	Υъ	2 3	70	173 04	696	8240	1530 O
1 ttrum	Ŷ	อ	39	68 905	4 47	1509 0	3030 0
Zinc	Z.n	2	30	65 37	714	4195	906 0
Zircinjum	Zr	4	40	91.22	6 49	1852 0	3580 0
	L						

<sup>\*</sup>The 103 chemical elements known at the present time are included in this thele. Some of those recently discovered have been obtained only as unstable isotopes.

<sup>†</sup> Based on Carbon 12 Figures enclosed in parentheses represent the mass number of the most stable motore.

<sup>‡</sup> Element sublimes unless under pressure

#### X. REFERENCE AND COLLATERAL READING

There are many excellent textbooks and periodicals available for reference purposes and for supplementary reading in chemistry and related fields. You will undoubtedly find some of these in your school library. A few representative ones are listed below.

INGRANIC Nebergall and Schmidt General Chemistry, D C Heath and Company Frey College Chemistry, Prentice Hall, Inc Sisler, Vander Werf, Davidson College Chemistry, The Macmillan Company

ORGANIC Wertheim and Jeskey Introductory Organic Chemistry McGraw Hill Book Company Noller Textbook of Organic Chemistry, W B Saunders Company Kelley Organic Chemistry, McGraw Hill Book Company Morri son and Boyd Organic Chemistry, Allyn and Bacon

Physiological Anderson Essentials of Physiological Chemistry, John Wiley and Sons, Inc. Hawk, Oser, Summerson Practical Physiological Chemistry, McGraw Hill Book Company Harrow and Mazur Textbook of Biochemistry, W B Saunders Company

FOOD AND NUTRITION Sherman Chemistry of Food and Nutrition, The Macmillan Company Mutchell and Bernard Food in Health and Disease, F A Davis Company Meyer Food Chemistry, Reinhold Publishing Company

MISCELLANEOUS Meyer Introductory Chemistry, The Macmillan Company
West Discovery of the Elements, Chemical Education Publishing Company,
Raston, Pa Moore A History of Chemistry, McGraw Hill Book Company

PERIODICALS In addition to the medical and nursing journals there are numerous periodicals which carry articles of interest to students of chemistry Such publications as the Journal of Chemical Education, the Scientific American, the Chemical and Engineering News, and Science are typical ones. A new periodical, Chemistry, by the American Chemical Society, is intended for advanced high school and for college students

In searching for suitable material for reports, etc., one should not overlook the better encyclopedias

#### LABORATORY WORK

#### To the Instructor.

At the beginning of each laboratory period the instructor should discuss the experiment with the class, outlining general procedures and clarifying objectives. This eliminates many minor errors, delays, and difficulties that develop if directions are not carefully read and followed

The experiments are so prepared that the student need answer only one specific question at a time. Each student's work should be individually checked at least once during the laboratory period. The student benefits by such conferences, and the instructor guins a better knowledge of each students ability. After the mistakes are corrected the instructor initials or rubber stamps the experiment (date accepted). No grade need be given at this time, this can be done at the end of the course. Such a method saves time for the student, makes it easy for the instructor to check the results, and helps him avoid the drivdgery of grading note-books after the laboratory period is over.

Since there are at least two laboratory exercises for most chapters, the first check may be made upon completion of the first exercise, which usually occurs near the middle of the period. Upon completion of all assigned work, before the apparatus is cleaned and put away, the student should bring the work to the instructor for a second and final check up. This method avoids a period end work inspection jam and results in a more orderly and efficient laboratory period. However, at times it may be more convenient to delay this final inspection until the start of the next laboratory period.

Many chemistry instructors in nursing schools are doctors or teachers from high schools and colleges, consequently they do not have the opportunity of becoming acquainted with each individual student in going over the laboratory work of a student, such an instructor is often embarrassed by inability to remember the students names. To avercome this difficulty, space has been left at the beginning of each Laboratory Exercise for writing in the students name date, and section.

Materials for each exercise usually can be kept in suitable cardboard or wooden boxes, labeled with the number of the exercise and materials lacking and then shelved. This procedure saves the instructor lime in getting material together for each exercise in the next semester course. Also the materials are conveniently ready for any student who is to make up on exercise.

#### PART V

# LABORATORY CHEMISTRY

#### THE STUDENT'S CHEMICAL WORKSHOP

A Laboratory Investigation. To test potency a scientist adds an iodophor to policy infected I ving it save cultures. Courtesy. West Chemical Products. Inc.



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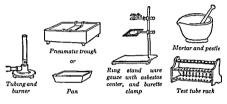
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# CHECK LIST OF APPARATUS

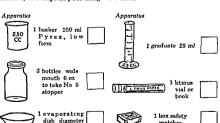
Section	Date	Name

# To the Student

- 1 Remove all apparatus from your assigned drawer and cup board and place on top of your laboratory desk
- 2 The pieces of general apparatus named and illustrated below are for the use of all sections Place them in the cupboard

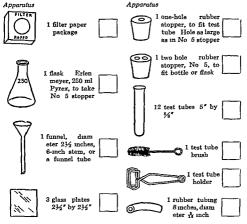


3 The following pieces of individual apparatus are to be checked. cleaned, and kept in your assigned drawer



3 inches

matches



4 To protect your clothing, provide yourself with a rubber or plastic apron or other outer garment (smock) unless one is provided Soap and a hand towel or wiping cloth are also desirable

# EXERCISE I—CHAPTER I PHYSICAL AND CHEMICAL CHANGES

Section

Dota

Name

MATERIALS Magnesium ribbon silver nitrate solution pieces of cloth potassium todide mercuric chloride sodium bicarbonate tartaric acid

#### Instruction

- (1) When a question is asked describe in detail what is observed, and where conclusions can be drawn state them briefly in this and all following experiments (2) Expressions preferably printed pertaining to all exercises must be done during the regular laboratory period (3) In carrying out the experiments keep in mind that in every chemical reaction there is a change in composition and in properties of the original substances involved along with an energy change
- (a) To STUDY THE CHANGE PRODUCED BY BURNING Examine a piece of magnesium ribbon noticing that it is a lustrous white flexible solid. Hold one end with your test tube holder and insert

the free end into a flame What happens?

Now examine the product magnesium oxide, and compare it with the properties of the original magnesium. How do they differ?

A chemical change as compared to a physical change involves (a) a change in composition of the substance (b) a change in at least some of its original descriptive properties and (c) an energy change Why is the burning of magnesium considered to be a chemical change?

(b) TO STUDY THE CHANGE PRODUCED BY LIGHT Place a drop of silver mitrate solution on a piece of white cloth and expose for some time to the light, preferably sunlight The dark appearing spot is amorphous silver What apparent evidence indicates that light has produced a chemical change?

(c) TO STUDY THE CHANGE PRODUCED BY HEAT: Place three or four crystals of potassium iodide and mercuric chloride in a mortar and grind until there is decided evidence of a change. The pink compound formed is mercuric iodide Why consider that heat (here

result of friction) may produce a chemical change?

(d) To Study the Change Produced by Water: Into a test tube place a pinch of sodium bicarbonate (baking soda) and an equal amount of tartaric acid crystals Add some water. Why consider that water is an agent that may bring about a chemical

change?

The mixture of baking soda and tartanc acid is very similar in composition to one type of commercial baking powder, and it is also used in making certain effervescing powders

(e) SUMMARY: A chemical change always involves a change in composition and corresponding energy changes. In some cases energy is required and in others energy is given out during chemical change. For example, burning of magnesium produces energy in

the form of light and , while to produce amorphous solver from a solution of solver nutrate, energy in the form of

is required.

#### Instruction:

Unless otherwise directed, always wash all liquids and soluble solids down the sink with plenty of running water. Waste solids, such as paper toweling, filter paper, and burnt matches should be placed in a waste paper container, while insoluble material, such as broken glass, should be placed in crocks provided for that purpose. Never put paper and glass in the same waste container. Ammonium hydroxide removes silver stains if not too old (p. 673).

# EXERCISE 2—CHAPTER I ELEMENTS, MIXTURES, AND COMPOUNDS

Section Date Name

MATERIALS Powdered sulfur (rhombic) powdered iron carbon disulfide, magnet magnifying glass

(a) Place five grams of sulfur and seven grams of powdered iron on separate sheets of paper. Observe their physical properties, i.e., state, color, magnetic properties, subhility of a pinch in one fourth of a test tube of carbon disulfide. Iron and sulfur are elements Grand together thoroughly in a morter the sulfur and iron. Place a pinch of the mixture on a piece of paper and examine with a magnifying glass. Can you distinguish the iron from the sulfur?

Hold a magnet near a small portion of the mix

ture Result?

What kind of a change?

(b) To a punch of the mixture in a test tube add about five milli liters (ml) of carbon disulfide (explosive near a flame), shake, and filter into an evaporating dish To filter, fold a filter paper in half, and then again at right angles to the straight edge. Onen the paner



g 1-Making a Filter Cond

as a cone, with a triple layer of paper on one side and a single layer on the other (Fig 1) Place in a glass funnel What is the dark substance that remains on the filter paper or in the test tube?

Allow the liquid (filtrate) in the evaporating dish to evaporate (do not heat)

What is in the solid residue?

What kind of a change has taken place?

(c) Place the remaining portion of the mixture in a test tube, clamp, and heat the lower part of the tube (Fig. 2), cautiously at first, then strongly to a red heat (10 min ) while noticing the different changes. What evidence

is there that chemical action took place in the muxture?

Allow the test tube to cool, and then break it in the mortar. Compare the physical properties of the substance left with the original mixture. Can you now distinguish between the iron and sulfur by means of a magnifying glass?

Incline test tube loosely clamped near mouth



Has the magnet any effect upon the substance?

Fig. 2—A Mixture Under Heat

Of what is the substance composed?

When elements combine chemically, do they retain their original properties? What is the new substance formed by

the combining of two or more elements?

Besides a change in composition and physical properties, what other characteristic do all chemical changes have?

How does a compound differ from a mixture?

(d) Summary: Complete the following statements An element is

A compound is

A mixture is

# EXERCISE 3-CHAPTER II

Section Date

Name

MATERIALS Two feet of glass tubing, triangular file; wing top.

To the Instructor: The technique required in the manipulation of glass tubing should first be demonstrated before the class, provided students have had no previous experience in glass working

(a) To CUT GLASS TUBING: Obtain from the supply table, or room, the materials listed above; lay the tube on the laboratory table, and with the file make a deep transverse scratch in the middle of the tube. Grasp the tube as shown in Fig. 3, holding the thumbs,







Fig. 4—Softening Glass Tubing by Heat Prior to Bending.

one on each side of the scratch, opposite to the side of the scratch, and push gently with the thumbs. For large glass tubing it may be necessary to make a deeper scratch completely around the tubing or rod

(b) To Bend Glass Tubing: Place the wing top on the burner, light the gas, and adjust the air holes at the bottom of the burner in order to secure a nonluminous flame. Hold the tube, as shown in Fig. 4 lengthwise, in the upper part of the broad flame, rotating it slowly so that the heat will be uniformly distributed on all sides. Continue the heating and rotating until the glass becomes soft enough to bend under its own weight. Remow from the flame and bend slowly to a right angle (Fig. 5). If the tube does not bend easily reheat and try again. Support the hot bend across some object so that the glass may cool slowly and not burn the desk. Later during the laboratory period when the glass is cool, make one arm of the right angle bend about two inches long, and the other end about five inches long.

Fire-polish the ends as directed in (c).

(c) To Fire-polish or Seal the End of Glass Tubing: Remove the wing top from the burner, and using the remaining half (one foot) of the original glass tubing (or a glass rod if provided), hold the end of the glass, as shown in Fig. 6, in the blue or nonluminous upper edge of the flame. This is a hotter flame than the yellow flame. Rotate the tube while heating, until you can see that the sharp edges of the glass are becoming soft and yellow in color. If the glass tubing is to be sealed at one end, or a glass rod is to be rounded, the tube or rod will need to be held for a longer time in





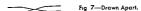
Fig. 5—Round and Flat Bends.

Fig. 6—Smoothing the End of a Glass Rod or Tube.

the upper and hottest part of this flame. Support the hot end so that it will cool slowly and not burn the desk.

If your right-angle bend is cool, cut to the dimensions as indicated in (b) and then fire-polish. Cut the sealed tube or rounded rod in the middle and preserve as a stirring rod.

(d) To Draw Out Glass Tubing: Using the remaining six-inch piece of glass tubing, heat lengthwise in the nonluminous flame until very soft. Remove it from the flame and immediately pull until drawn out, as shown in Fig. 7, to a little over half again its original



length. Cool and cut in the center. Save one as a dropping tube or pipette. Submit the right-angle tube and the stirring rod to the

Instructor for inspection and credit

Instruction: Remember that broken glass is to be placed in a separate waste container.

# EXERCISE 4—CHAPTER II MEASUREMENT OF LAROPATORY VESSELS

Section Date Name

MATERIALS Graduated cylinder, various vessels in laboratory drawer, balance

Note The metric system of measurement is used in all scientific measure-

ments The unit of length is the meter (39 37 inches) which is divided into 100 centimeters (Fig. 8)

The unit of volume is the liter (1.05 quarts), which is composed of 1000

The unit of rollme is the titler (1 to quarts), which is composed of 1000 millulers (ml) frequently called cubic centimeters (cc) The unit of weight is the kilogram which is the weight of 1000 millulers of water at 4° C (Fig. 9) Each milluler of water weighs one gram

#### Remember

- 1 meter (m) = 100 centimeters (cm) = 1000 millimeters (mm)
  - 1 liter (1) = 1000 milliliters (ml) or cubic centimeters (cc)
  - 1 kilogram (kg) = 1000 grams (Gm) = 22 pounds

STANDARDS OF LINEAL MEASUREMENT CENTIMETERS

o wen s

2 54 centimeters equals one inch
Fg 8—What Are the Advantages of
These Two Standards?

n) = 22 pounds



I ml. of water weighs I Gm

Fig 9—How Is This Used in Chem stry of

(a) A MENTAL CONCEPT OF VARIOUS VOLUMES Add water to the graduated cylinder until the lower part of the curved surface, called the meniscus, reads 5 ml Pour this water into one of your test tubes and mark the upper level of the water Add 5 ml more of water and mark the upper level, and remember the approximate amount to be used when an experiment calls for 5 or 10 ml of a liquid Add sufficient water to fill the test tube, and measure the

amount by use of the graduate Record it Remember this volume held by the test tube, so that you can make ap proximate measurements in the future It is also convenient to know how much of the lower curved portion of the test tube is required to hold I ml Try it

(b) APPROXIMATE VOLUMES OF OTHER LABORATORY VESSELS Pour 25 ml, 50 ml, and 100 ml portions of water into your beaker.

flask, and evaporating dish until you know the approximate amount of liquid contained in these vessels, or parts of them.

Test tube holds	ml
Beaker holds	ml.
Flask holds	ml
Evaporating dish holds	ml.
Bottle holds	mi

In all following exercises estimate instead of measuring metric volumes, unless unusual accuracy is required.

(c) MEASUREMENT OF WEIGHTS. The trip scale, triple beam balance with a capacity of 610 Gm. and a sensitiveness of 0.1 Gm makes a very satisfactory balance for general laboratory purposes. Time is saved in weigh-

ing and no weights are ever lost or misplaced. Place a beaker on the left pan of the balance and weigh (Fig. 10). Pour 100 ml of water into the beaker and weigh agam Record the weights below. If density is the weight divided by the volume, what is the density of water in grams per milliliter?

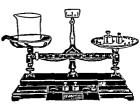


Fig 10—Laboratory Balance for Weighing

Record your figures in the following table:

Wt of beaker + water	Gm.
Wt. of beaker	Gm
Wt of 100 ml of water	Gm
Density of water in grams per ml	Gm

Considering that hydrochloric acid has a density of 1.2 grams per ml., what would be the weight of 100 ml. of hydrochloric acid?

(d) SUMMARY: In scientific measurement the system is used. Its chief advantage less in its case of making calculations, since the relationship between the units is on a basis of ten.

## EXFRCISE 5-CHAPTER II LIMEWATER

Section

Date

Name

Limewater is a saturated solution of calcium hydroxide. It should contain not less than 0.14 per cent of Ca(OH)2 at 25° C Preserve at in well-filled tightly stoppered bottles

MATERIAL Lime

Fill the curved bottom of a test tube with powdered lime. Fill the test tube almost completely with distilled water and shake vigorously for several minutes in order to form a saturated solution of the white solid, namely, calcium hydroxide. Filter (Fig. 11) and use the clear limewater for the rest of the experiment,







Fig 12-Heating

- (a) Using freshly prepared honewater, record the taste
- What is its action on red litmus paper?
- (b) Complete the equation for the reaction which takes place when water is added to quicklime by making the formula for calcium hydroxide.

What is a common name for the white solid formed?

# Is it very soluble?

(c) Pour several drops of limewater on a glass plate and allow to stand exposed to the air for a few minutes. By means of a glass tube blow air through some limewater contained in a test tube. Observe the formation of a white insoluble precipitate \* Complete the equation for the reaction by making the formula for calcium carbonate

What is the name of the solid formed?

What is the scum formed on the surface of the limewater on the glass plate?

Why should limewater be preserved in well-filled, tightly stoppered bottles?

(d) Instruction: When heating a liquid in a test tube (Fig. 12) always hold the tube in an inclined position with the mouth of the tube away from anybody, and slightly agitate the liquid by a sidewise shaking of the tube. Never heat the tube above the surface of the enclosed liquid.

Heat some clear himewater in a test tube Examine carefully in a good light. Does the solubility of the calcium hydroxide in the water increase or decrease with rise in temperature?

(e) SUMMARY: A filtrate is defined as

A saturated solution is

The test for carbon dioxide is

Do all solids increase in solubility with rise in temperature?

Any remaining time may be devoted to practice in formula and equation writing.

<sup>\*</sup> A precipitate is an insoluble substance formed in a liquid. In some cases the precipitate does not settle out, but remains suspended and imparts a cloudiness to the liquid.

O2

#### EXERCISE 6-CHAPTER III OXYGEN: PREPARATION AND PROPERTIES

Section Mata Name

MATERIALS Potassium chlorate, pulverized manganese dioxide, charcoal, sulfur, sodium, steel wool Deflagrating spoon (most satisfactorily made from 8 inch piece of heavy soft iron wire, flatten at the end and bend at right angle)

#### Preparation:

Add to about one-third of a test tube of potassium chlorate, onetenth as much pulverized manganese dioxide (catalytic agent). Place your thumb over the mouth of the test tube and mix contents of the tube by shaking it Push (by a rotary motion) the moistened end of a right-angled glass tube, into a single-hole rubber stopper which fits this test tube Moisten the end of a piece of narrow rubber tubing eight inches long, and slip it over the other end of the right-angle tube. Place the stopper in the test tube and clamp the tube in a horizontal position Tap the test tube gently in order to distribute the mixture along the lower side (Fig. 13).



Partly fill the pneumatic trough with water and invert in it three bottles filled with water. Heat the test tube gently, so that there will be a slow evolution of oxygen Now collect three bottles full of gas, covering each when filled with a glass plate and set them mouth upwards on the table. The slight cloud that is often present when oxygen is prepared from potassium chlorate and manganese dioxide is due to an impurity and shortly disappears if the gas is left to stand over water.

Complete the following equation: 2 KCIO:

Potassium chlorate → Potassium chloride + Oxygen

#### A. PHYSICAL PROPERTIES

From observations and study state the physical properties of oxygen, namely: Physical state , color , taste and solubility in water .

#### B. CHEMICAL PROPERTIES

(a) CARBON: Lower a piece of glowing charcoal contained in a deflagrating spoon into one bottle of oxygen (Fig. 14) and keep there until all action is over. Remove the spoon and cover the top of the bottle with a glass plate. Result?

Of what is the resulting gas composed?

The chemical name for the product formed is

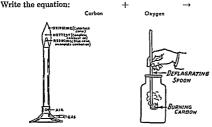


Fig 14—Does Carbon Have an Affinity for Oxygen?

Remove the glass plate and add one-half a test tube of water. Close with the hand and shake thoroughly for at least a minute m order to dissolve all of the gas in the water. Place a strip of blue

litmus paper in the bottle. Result?

Litmus paper turns red in the presence of an acid, and all acids contain hydrogen. Litmus paper turns blue in the presence of a base, and all bases contain oxygen bound to hydrogen in what is known as a hydroxyl group (OH). Verify by looking at the formulas on the bottles of acids and bases.

Does the oxide of carbon dissolved in water form an acid or a base?

Pour the solution into a clean test tube, and to this solution add a few milhiters of innewater. If there is no apparent change, look down through the liquid in the test tube in the presence of good light. Result?

Calcium hydroxide (limewater) is a test for carbon dioxide and for carbonic acid (n. 649).

(b) SULFUR: Put a pinch of sulfur in the deflagrating spoon and hold in the upper part of the laboratory flame until the sulfur begins to burn (kindling temperature). Observe the color and the size of the flame. Now lower the burning sulfur into a bottle of oxygen. Result as to chappe?

Remove the spoon, cautiously smell the gas in the bottle by fanning some of the gas toward you with your hand Describe the odor.

Of what is the gas composed?

Write a possible name for this gas

Considering the valence of sulfur to be four, write the equation

Place both red and blue litmus paper in the bottle, add one half a test tube of water, close with the hand and shake. What does the change in color of the litmus paper indicate?

(c) SODIUM: (Demonstration by Instructor.) Clean the spoon and place a small piece of metallic sodium on it. Hold at arm's length, warm until the sodium begins to burn and then immediately thrust it into a bottle of oxygen. Result? Of what is the product composed?

Is it a solid or a gas?

Write a possible chemical name

for the product formed

Write the equation



Place both red and blue litmus paper in the bottle, add a little water, remove the spoon, close the mouth of the bottle with your hand and shake it. Result?

What does the color indicate?

(d) Iron: Twist a piece of steel wool around the spoon end of the deflagrating spoon. Ignite it and immediately lower it into a bottle of oxygen. Result?

Observe the solid combustion product. The compound formed, magnetic oxide, Fe<sub>3</sub>O<sub>4</sub>, is a combination of ferrous oxide and ferric oxide. Write the equations for the formation of each oxide.



(e) What is formed when elements burn in oxygen or air? Make a general statement as to the relative

intensity of burning in oxygen and in air.

When oxides of elements combine with water and give acid reactions to litmus paper those elements are classified as nonmetals. When oxides of elements give a basic reaction (turn red litmus blue) in water, these elements are classified as metals. How would you classify sulfur . carbon

and soduim?

Any oxide of an element which

combines with water to form either an acid or a base (hydroxide) is called an anhydride. The nonmetallic oxides that form acids are called acid anhydrides. Likewise the metallic oxides forming bases are called basic anhydrides. Anhydride means "without water." In the following equations:

$$H_2O + CO_2 \rightarrow H_2CO_3$$
 Carbonic acid  
 $CaO + H_2O \rightarrow Ca(OH)_2$  Calcium hydroxide

the acid anhydride is

while

is a basic anhydride.

#### Summary:

In the preparation of oxygen from potassium chlorate, why is manganese dioxide called a catalytic agent?

Is oxygen active at ordinary temperatures?

An oxidizing agent, as potassium chlorate, is one that.

Kindling temperature is defined as

The products of oxidation are called

Anhydrides are of metals or nonmetals An element whose oxide reacts with water to form a base is classi-

fied as a

If an acid is produced the element is classified as a

#### Instruction:

Disconnect glass tubing in this and all following experiments from rubber stoppers and tubing before leaving the laboratory.

# EXERCISE 7-CHAPTER IV WATER: DISTILLATION OF WATER

Section

Date

Name

MATERIALS Potassium permanganate crystals, salt, phenolphthalein solu ion, bent glass condensing tube

(a) Set up the apparatus as shown in Fig. 15. Pour into the flask 100 ml. of water and add two or three crystals of potassium permanganate and a big pinch of salt. Heat the contents of the flask to boiling and collect a few milliliters of the condensed steam (distillate) If there is no distilled water in the laboratory you will need to collect approximately two test tubes for the next experiment. Is the process of distillation

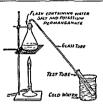


Fig 15—Distillation of Water.

physical or chemical?

Taste the distillate. What two evidences are there that the water has been purified by distillation?

What substances in the original liquid do not vaporize under the conditions of the experiment?

How could salt water be

converted into fresh water?

Record the taste of the distilled water

How do you account for the taste of boiled or distilled water

Suggest a method for improv-

ing its taste

(b) Add a drop of phenolphthalein to some distilled water in a test tube. (Phenolphthalein is an indicator which turns red in the presence of a trace of a strong alkali.) Result?

To a test tube of tap water add one drop of concentrated ammonia water\* (ammonium hydroxide, NH<sub>4</sub>OH) and a drop of phenolphthalein. Result?

Phenolphthalein is used as a test for any hydroxide solution.

(c) Almost fill one of your six-ounce bottles with tap water, and by means of a clean, dry dropping tube or glass rod, remove and add one drop of concentrated ammonia water. Pour into a clean flask and distill. Collect one-half a test tube of the distillate in each of six clean test tubes; each test tube containing one drop of phenolphthalein. When the water in the beaker becomes hot, change it for cold water. (If Exercise 8 is to be performed, proceed with it while collecting the six tubes of distillate) Save and check the

six tubes with the Instructor

What evidence

is there that the ammonia passes over with the steam?

Do the first portions of the distillate contain more or less ammonia than the latter portions?

In what manner does ammonia, as an impurity, differ from the salt and potassium permanganate of part (a)?

From what type of impurities can water be freed by distillation?

(d) Place four or five drops of the distilled water in a clean evaporating dish and evaporate, holding the evaporating dish a few inches above the tip of the flame. Is there any residue?

Repeat, using city water.

Why is distilled water used for so many laboratory experiments in preference to city water?

<sup>\*</sup> See Fig 17, page 667, for technic of removing stopper, pouring, and measuring, if not previously taught

# EXERCISE 8-CHAPTER IV SOFTENING HARD WATERS

Section

Date Name

MATERIALS Saturated calcium sulfate solution, magnesium sulfate solution (1 2500), borax, sodium carbonate, sodium phosphate, clear soap solution, distilled water Read Soap, pages 361-365

(a) To a test tube half full of distilled water add a drop of soap solution. Close the mouth of the test tube with your thumb and shake the tube thoroughly. Allow the tube to stand undisturbed

for about two minutes. Are the suds permanent?

Has a precipitate formed in the solution?

- (b) Using one-half a test tube of faucet water instead of distilled water, repeat (a). If permanent suds do not form with one drop of soap solution, continue adding soap solution and shaking until the suds formed are permanent. Has a precipitate formed?
- (c) Using one-half a test tube of distilled water which has been made hard by the addition of a few drops of calcium sulfate solution, repeat experiment (b). How do your results compare with those in (b)?

When suds form, has hard water been made soft?

Can soap be used to soften hard water?

(d) Using one-half a test tube of distilled water which has been made hard by the addition of a few drops of magnesium sulfate solution, repeat experiment (b). Are the results similar to those

of (c)?

(e) Using one-half a test tube of distilled water which has been made hard by the addition of a few drops of either magnesium sulfate or calcium sulfate solution, add a sufficient number of drops of soap solution to produce a precipitate, but not enough to form suds upon shaking. Rub a small amount of the precipitate between your fingers. Results?

State your reasons why hard water is unsuitable for laundry use

- (f) Evaporate a few milliliters of water rendered hard by either calcium or magnesium salt solutions. State your reasons why hard water is unsuitable for steam boilers.
- (g) Dissolve a pinch of sodium carbonate (washing soda) in one half a test tube of hard water, add a drop of soap solution and shake the tube thoroughly Continue adding soap solution and shaking until suds form Keep in mind the number of drops of soap used Instead of washing soda, use borax and repeat again. Repeat again, but this time use sodium phosphate Conclusion.

Complete the following indicated equations

Summary Hard water contains, primarily, compounds of the metals and

Hard water may be softened by the addition of

# EXERCISE 9-CHAPTER V

Section Date Name

MATERIALS: Potassium nitrate, "hypo," copper sulfate crystals, sheet gelatin, animal charcoal (bone black), dilute litmus solution, sodium chloride solution. Silver nitrate solution. (The carrot demonstration, Exercise 10 B (c) should be started at the bermning of the laboratory period by the Instructor.)

#### A. THE FFFECT OF TEMPERATURE UPON SOLUBILITY

(a) Measure out two-thirds of a test tube of powdered potassium nitrate. Add this, a little at a time with constant shaking, to a test tube containing 5 ml. of water. When no more will dissolve, pour this solution into another test tube. Feel the lower part of the test

## tube. Result?

Heat slowly this saturated solution of potassium nitrate until it begins to steam, adding potassium nitrate in small amounts with constant shaking or agitation, until no more salt dissolves. Allow this test tube solution to cool to the temperature of the room. Does it require much more potassium nitrate at a high temperature than

it does at a lower temperature for saturation?

Compare and record the effect of temperature on the solubility

(b) Recall or repeat the experiment (p. 649) on the effect of heating one-half a test tube of limewater. Does an increase in temperature always increase the solubility of a solid?

## B. SUPERSATURATED SOLUTIONS

(a) Fill a test tube one-half full of sodium thiosulfate crystals ("hypo"). If the "hypo" crystals are covered with a white powder due to the loss of water, a few drops of water must be added. Sodium thiosulfate, Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> · 5 H<sub>2</sub>O, is chosen since it already contains sufficient water to make a solution at higher temperature. Heat cautiously with a small flame until a clear solution results. If necessary, raise to the boiling point. Place the test tube in a beaker or bottle of water and allow to cool undisturbed. If a solid should settle out, redussolve by heat and repeat the experiment. The solution is now supersaturated. Drop a tiny crystal of "hypo" into the cold liquid. Result?

Feel the lower part of test tube. Result?

Substances which crystallize out of solution always show this change of temperature, e. g., water to ice. The heat absorbed when the "hypo" dissolves equals the heat given off when it crystallizes. Crystalline substances when added to water as in (a) upon being dissolved always absorb heat. Advantage of this fact is taken in preparing freezing mixtures. In fact whenever a substance changes its state, heat is either liberated or absorbed. This principle is applied in refrigeration.

## C. FACTORS IN MAKING A QUICK SOLUTION

A mass dissolves at its surface only. The larger the total surface, the faster it dissolves Therefore, when a solution is to be prepared quickly, the solid should be powdered.

(a) Take two crystals of copper sulfate of equal size, which will slip into a test tube. Place one crystal in a test tube and, after pulverizing the second crystal in a mortar, place the powdered copper sulfate in a second test tube Fill each test tube two-thirds full of water. Place your thumb over the mouth of each tube and shake it gently, noting the time for the powder to go into solution What fraction of the original crystal remains in the first tube?

To save time, in what form should you use a solid to be quickly dissolved? Save for 10B (a) the tube containing the dissolved powdered copper sulfate.

(b) Warm the test tube containing the undissolved copper sulfate. What effect has heat upon solution?

(The color of the solution will indicate the amount of copper sulfate that has dissolved.)

(c) Would stirring aid in dissolving a solid? Why?

In the process of digestion foods are changed into soluble substances. Why, then, should food be well chewed?

Solution of a solid in a liquid is hastened by several factors, namely , and

## D SOME PROPERTIES OF COLLOIDS

(a) ADSORPTION Heat about one gram of animal charcoal (bone black) in a porcelain dish for a few minutes. This is to activate the charcoal by expelling the occluded gases. When the charcoal has cooled place enough of it in a test tube to fill the rounded portion of the tube. Add enough didute litmus solution to half fill the tube and shake the tube and its contents vigorously for at least one minute. Filter out the charcoal through two thicknesses of folded filter paper (or one sheet of quantitative paper) and compare the filtrate with some of the original litmus solution. Result?

The condensing of gases or dissofved substances on the surface of colloids is called

(b) Imbibition Cut sheet gelatin into two equal sized pieces, about ¼ by ¼ inch Place one piece in a test tube and cover with cold water After several minutes compare its size with the remain

ing dry piece of gelatin Result?

The swelling of a colloid in a water solution is called

Save the gelatin-water solution for (c).

(c) PROTECTING ACTION OF A COLLOID: To keep dispersed material from running together and forming larger particles which

settle out a protective colloid may be used.

To one-half a test tube of sodium chloride solution add five drops of silver nitrate solution and stir thoroughly with a glass rod. Place in the test tube rack.

To another test tube one-half full of sodium chloride solution add about I ml. of gelatm solution saved from (b), mix thoroughly, and then add five drops of silver nutrate solution. Stir thoroughly with a glass rod and stand in the test tube rack along side of the other tube Observe from time to time as you proceed with your other experiments.

In the one tube a precipitate of AgCl formed and settled. In the test tube containing the gelatin, the AgCl remained suspended in

what is called a state.

How do you imagine gelatin acts as a protective colloid?

# EXERCISE 10-CHAPTER V DIFFUSION, OSMOSIS, DIALYSIS

Section Date Name

MATERIALS Copper sulfate solution, 0.85 per cent sodium chloride solution, saturated potassium ferrocyanide solution, carrot, saturated sugar solution or molasses, bit, blood lancet or needle, starch, iodine solution, copper sulfate, collodion (or cellophane sausage skins obtained from Visking Corporation, Union Stock Yards, Chicago, or vegetable parchment in 6° x 6° sheets, "Patapar," in box of 1000 sheets), thread in

To the Instructor: To save time part B lends itself to demonstration.

#### A. DIFFUSION

The a thread to a crystal of copper sulfate and suspend it in a test tube of water. Hold the tube before your eyes in a strong light and observe what is happening.

What name is given to this phenomenon?

What causes the dissolved particles to move?

Where is the pressure greater?

Where is the concentration greater?

#### B. OSMOSIS

(a) Fill a test tube with a copper sulfate solution (decided blue) and introduce into this solution a drop of concentrated solution of potassium ferrocyanide by letting it drop from a glass dropping tube, the end of which is just above (1 cm.) the surface of the copper sulfate. (If the drop falls to the bottom and breaks, repeat the experiment, using a stronger solution of copper sulfate) Red copper ferrocyanide is precipitated, forming a semipermeable membrane, which surrounds the drop

In a few minutes observe the drop. What has happened to the size of the drop?

Explain what produces this result

(b) Dissolve a drop of blood\* into a test tube full of distilled water, and another drop into a test tube full of physiological saline solution.

How do you account for the fact that in one test tube there is a turbid suspension of blood cells, while in the other, only a clear, pinkish red solution?

The result obtained in (a) and (b) is analogous to that of introducing into the body a hypotonic salme solution after a hemorrhage. This is an illustration of what?

If a drop of dilute copper sulfate were added to a concentrated solution of potassium ferrocyanide, the drop would shrink. This is an illustration of what?

(c) (Demonstration by Instructor): Use a bit or cork borer and make a hole about halfway through a carrot, beginning from the top.† Then fill the hole with molasses or saturated sugar solution

<sup>•</sup> Use a sterilized blood lancet or needle to obtain blood from the ear lobe or finger † If the carrot is old, it may be necessary to scrape off lightly the outside epidermia with a knile.

Fit the hole tightly\* with a one-hole stopper, holding a glass tube about one yard long, and immerse the lower half of the carrot in a beaker of water (Fig. 16). Label the level of the sugar solution in the glass tube, and allow to stand an hour or until the next day. Why does the solution rise in the

tube?

Besides in the blood, where does osmosis occur in the body?



The passage or diffusion of solvent molecules is called

Fig. 16—Osmosis In a Carrot.

#### C. DIALYSIS

- (a) DIALYZING TUBE: Prepare a collodion bag by filling to the top a dry, clean test tube with collodion. Pour the collodion immediately into the original container, invert the test tube and clamp it to a ring stand. While the collodion bag is drying proceed to (b). After about five minutes, when no odor of ether is noticeable, fill with tepid water, loosen the edges of the film at the rim of the test tube with your fingernail or some sharp instrument such as a knife, and then with a pencil between the membrane and the test tube carefully loosen the membrane to the bottom of the tube. Proceed to (c).
- (b) COLLOID AND CRYSTALLOID SOLUTIONS: Prepare a colloidal starch solution by bringing to the boiling point less than a pinch of starch (the amount that would stick to one finger) in half a test tube of water. Prepare a crystalloid solution by dissolving (do not heat) sufficient copper sulfate in half a test tube of water to impart to it a clear deep blue color. Hold both test tubes in a ray

of light. How does the colloidal solution look?

Melted paraffin or candle grease dropped around the inserted stopper will assure a tight fit.

Filter the starch solution and when cool test a few milliliters of the filtrate with one drop of dilute iodine solution. A blue color indicates the presence of starch. Can a colloid be separated by filter

paper?

Mix the two solutions of copper sulfate and iodine free starch, and save for (c). Finish (a).

(c) DIALYSIS: Using a pencil or tube, carefully loosen and remove the collodion membrane from the test tube, pour out the water, partially fill it with the mixture of copper sulfate and starch. Wash off any solution spilled on the outside of the bag, lower the bag into a 25 ml. graduate or beaker half full of water (preferably dastilled), allowing the top of the membrane to hang over the rim of the glass. At the end of five minutes or more remove the bag and look down through the liquid in the graduate The blue color

inducates the presence of Add a drop of iodine to the water in the graduate or beaker. Is there any starch

in the distilled water?

What type of solutions

are retained by a membrane?

Are colloidal particles larger or smaller than the molecules of crystalloids? Would you think that colloidal foods, such as starch, proteins, and emulsions, would be di-

rectly absorbable from the alimentary canal?

Before colloidal foods may be absorbed through the intestinal wall into the blood stream they must be disintegrated into a more finely dispersed state by the chemical process called

In a post-mortem examination following the suspicion of poisoning with a metallic salt, such as that of lead, arsenic, or copper, the separation of the crystalloid from the colloidal material of the

body (food, albumin, etc.) is done by a process called

Define dialysis

# EXERCISE 11-CHAPTER VI

Section Date Name

MATERIALS Glacial acetic acid, cone sulfuric acid, zinc, calcium hydroxide, sodium chloride, silver nitrate, sugar, ethyl alcohol, chloroform, and silver nitrate solution

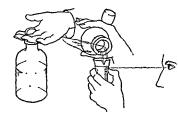


Fig 17

Instruction: Study drawing for technic of removing stopper, pouring, and measuring. In case acids, bases, or other chemicals are spilled or spattered on clothing or skin, or in the eyes, wash immediately with large quantities of water (preferably running water). Have someone notify the instructor.

#### A. FLECTROLYTES

1. Acros (a) Into a dry test tube pour about 2 ml of glacial acetic acid obtained from the supply table. Dip a dry glass rod into the acid, transfer a drop of it to an evaporating dish, and then lay a strip or piece of dry blue litmus paper on the top of the drop of acid

Is there any immediate action noticeable?

Add a drop of water to the acid and the blue litmus paper. The color of the litmus is now What is necessary

for the acid to react with the blue litmus?

(b) Drop a small, dry piece of zinc into 2 ml of concentrated sulfuric acid contained in a test tube. Is there much evidence that a gas is being evolved?

Into a second test tube half full of water, slowly pour the acid and then add the zinc Besides the heat generated what apparent evidence is there that chemical action is taking place?

What is necessary for the acid to react with the metal zinc?

Does the dulute H<sub>2</sub>SO<sub>4</sub> show any properties that concentrated H<sub>2</sub>SO<sub>4</sub> does not show? Will zinc readily displace H<sub>2</sub> from concentrated sulfunc acid that is not diluted or

10mzed?

The reactions in (a) and (b) are the result of ionization,\* and to cause ionization must be present. Write the equation for the ionization of sulfuric acid, that is, show how the acid molecule breaks up in water, one part becoming positively charged and the other negatively charged.

What ion is responsible for the characteristic action of acids?

2 Bases Place a piece of dry red litmus paper upon a pinch of dry calcium hydroxide Result? Add a few

drops of water The color of the litmus is now

Does water bring out any properties which the dry material does

not indicate? Do dry hydroxides give the

test for hydroxyl ions? Red litmus paper

turns in the presence of hydroxyl ions
Write the equation for the ionization of calcium hydroxide showing
the formation of positive and negative fragments

Co(OH)→ \_\_ +\_ -

<sup>·</sup> Refer to text for explanation of ionization

What ion is responsible for the characteristic action of bases?

3. SALTS. Dissolve one crystal of sodium chloride and one very small crystal of silver nutrate in separate clean test tubes containing a few ml of distilled water. Mix the two clear solutions Result?

Silver nitrate solution is used as a test for the chloride ion. If an electrolyte (acid, base, salt) is insoluble, will it show ionization?

Remembering that the salt, silver chloride, is unsoluble, complete the following ionic equation

#### B. NONELECTROLYTES

Rinse three clean test tubes with distilled water. In one test tube containing distilled water dissolve a few crystals of sugar (C<sub>12</sub>H<sub>2</sub>O<sub>11</sub>), and in another test tube containing distilled water dissolve a few millihiters of alcohol (C<sub>2</sub>H<sub>5</sub>OH) Mix in the third test tube a few millihiters of chloroform (CHCl<sub>3</sub>) and distilled water. Make a test for the hydrogen ion with blue litmus paper, the hydroxyl ion with red litmus paper, and the chloride ion with silver nitrate solution. Do you get positive tests for these ions?

Summary: What classes of substances ionize?

In general if a rapid reaction takes place in solution, is it probably between ions or molecules?

Which are more active chemically in

solution, electrolytes or nonelectrolytes?

Why do nonelectrolytes not ionize?

What type of valence exists in nonelectrolytes and compound radicals?

# EXERCISE 12-CHAPTER VI STAINS

Section	Date	Name	 	••••	
					_

MATERIALS Bleaching powder, sodium carbonate, saturated oxalic acid solution, hydrogen peroxide, potassium permanganate, citric acid solution, Carbona, alcohol, turpentine, borax, "hypo," ammonium hydroxide, starch Pieces of muslin discolored by various stains, as ink, paint, mildew, etc.

Stains of a physical nature, such as a grease spot, are easily removed by finding the right solvent; but if the stain has been formed by a chemical action, as an ink spot, then a chemical reaction is necessary to change it over into a soluble form so that it may be washed out.

Home and Garden Bulletin no. 62 of the U.S. Department of Agriculture, on the removal of stains, may be obtained at nominal cost by writing directly to that Department. If this bulletin is available, remove all stains from the pieces of cloth given you by the Instructor according to the methods in this bulletin, or in the accompanying directions

# Chlorine Bleach:

Place 10 Gm. of bleaching powder (chlorinated lime) in a 250 ml. beaker. Add a solution of 10 Gm. of washing soda dissolved in 100 ml. of water. Stir thoroughly, allow the mixture to settle, and filter the supernatant liquid. This clear solution is a good bleach. but must not be left too long on the clothes. When treating stains with this solution, stretch the stained portion over an evaporating dish, or a beaker, and apply the bleach with a medicine dropper or glass tube. Neutralize the chlorine bleach with oxalic acid solution and rinse well in water. Repeat many times if necessarv. Ink eradicators are composed of such solutions. Chlorine bleaches must not be used on animal fiber.

# Potassium Permanagnate:

Dissolve several crystals of potassium permanganate in less than a milliliter of water so as to make a concentrated solution. Apply to the stain with a glass rod or tube, and allow it to remain for five minutes on the stain. The brown stain is removed by applying hydrogen peroxide made slightly acid by a drop of hydrochloric acid. Repeat if necessary. Rinse well.

Obtain from the Instructor pieces of stained goods. Remove

the stains and return the goods for record.



Fig. 18—Stain Removal. Treating a stain on nonwashable article with sodium perborate bleach. Apply a solution of sodium perborate. Rise well using a small syringe to force water through the spot and sponge to absorb the water Courtery. U. S. Department of Agriculture.



Fig 19—Stan Removal Applying a grease solvent Place fabric stained a de down on a pad of absorbent material Sponge back of stan in with pad dipped into grease solvent. Apply only a little solvent at a time. Work from center of stan a toward outside ledge using light brushing or tamping motion. Courtesy U.S. Department of Agraculture.

Stain	Methods of Removing Some Common Stains
Alkalı	Yellow discolorations from an excess or careless use of washing soda borax ammonia and atteng alkali soaps are removed by washing in water or by treatment with a mild and as lemon juse (circle said) white vinegar (4 per cent scettic scid) and orable and solution. Russe- repeatedly
Blood	Fresh blood stans on wash goods are removed by soaking in cold water and the washing in Lakes was noap solution. Fresh statins on dothing at lake and wool are aponged in the stating on the stating of the latter than the state of the state
Chocolate Coffee	Fresh stains on washable goods are removed by stretching the goods across a supporting structure (bowl) and allowing hot water to run through them Wash in hot soap solution if pacesary use a chlorine bleach. Fresh stains on unwashable goods are sponged with warm water Any remaining grease spot from the cream used may be removed by a grease solvent as Carbona and naphthu.
Cod Liver Oil	Soak in kerosens one hour boil in soap solution ten minutes and russe in warm water
Cosmetics	Locatick nail polish and rouge may frequently be removed by ordinary washing. Any remaining states can be dissolved by Carbona or acetone, to be followed by a chlorine bleach which is warm.
Egg	Scrape off as much egg as possible Wash or sponge the goods with luke warm water Launder wash goods in warm soep solution. Any remain ing grease spots are removed by grease solvents
Fruit (dyes)	Fresh fruit stains on washable goods are usually soluble in running cold or hot water A 50 per cent alcohol solution will generally remove fruit stains from fish first ure harder to remove than those from cooked fruits. Stains from fash fruit are harder to remove than dare they begon. Lemon juece or a chlorine bleach on the goods and exposure to the sun will bleach most stains.
Grass	Wash and rub washable goods in cold water For clothing silk or wool sponge with 50 per cent alcohol. A chlorine bleach will remove grass stains.
Grease (milk cream)	Grease spots with the exception of dark grease stains are removed by  (a) Laundering wash goods (b) Using grease solvents (insplitta Car bona either benzol) on good over a blotter or towel and working from the outside of the spot toward the center (c) Using dry absorbents (starch French chalk, tabum powder) work in absorbent and when gummy, brush off and repeat again.

Starn	Methods of Removing Some Common Stains
Ink (ordinary)	When fresh most inks are soluble in running cold water in sweet milk (colored goods) in sweet or sour milk (white goods) in lemon juice salt mixture supose to the sun. Fresh or old nik stains may be removed by the chlorine bleach or permanganate method
Iodine	Soap water ammonia solution and rinsing in hot water removes iodine Alcohol removes iodine from the skin.
Meat juice	Same methods as for blood
Mercuro- chrome	Washed out by regular laundry methods Alcoho containing a drop of HNOs or 'hypo will remove Mercurochrome from the skin
Mildew	Launder and dry $m$ the sun or try the milk and lemon successit methods as in the case of inks
Paint (varnish tar and shellac)	Sponge fresh spots with paint solvents (turpentine naphths benzol) Almost dry spots on washable goods may be softened with lard or but ter and then removed by washing and rubbling in a warm sosp solution Shellac is soluble in 50 per cent alcohol
Pierie Acid	Boil in dilute sodium hydroxide solution for 30 minutes and then follow with a chlorine bleach
Rust	Lemon juice salt mixture (see inks) warm oxalic acid solution chlorine bleach
Salad	For a salad dressing containing eggs and cream sponge with warm water For a vinegar or letnon dressing wash in cold water then in sosp so- lution and finally rinse in any fat solvent (naphtha) if an oil spot re- mains
Scorch	Scorches on linen or cotton may frequently be removed by rubbing with soap and water or mostening with water and exposing to the sun Scorched wood and slik may seldom be removed Sand papering or rubbing a scorch ou woolen goods and then sponging with hydrogen percude often removes slight scorched type.
Silver Salts	Sodium thosulfats (hypo) removes silver stains if not too old Also some silver stains may be removed from the skin by first treating with iodine and then with d'lute ammonia water
Tea	For wash goods boil in strong soap solution: Sponge wool and silk Sometimes a stain may be removed by mostening with water working borsx into the stain allowing to stand a few minutes and then rinsing in boiling water
Varmsh	Sponge with acetone
Vaselme	Hot water sets Vaseline spots. Turpentine is a solvent for Vaseline Re move turpentine with a gresse solvent

# EXERCISE 13-CHAPTER VII

Section	Date	N	ame						
MATERIALS	Sodium	carbonate,	sodium	chl	orıde,	copper	oxide,	and	mag

(a) COMPOSITION: The formulas of hydrochloric, nitric, and sulfuric acids are

How are acids similar in composition?

about 10 ml of water, prepare dilute solutions of each of the following acids by adding two drops of hydrochloric, nitric, and sulfuric acids to the water in each test tube. Drop into each tube a small piece of blue\* htmus paper. Results?

(b) ACTION ON LITMUS: In three test tubes, each containing

Now drop a piece of red

litmus paper into each solution. Results?

- (c) TASTE: Taste a drop of the dilute acid solutions which contain the litmus paper. Result?
- (d) ACTION ON A SALT: Put a pinch of common salt into a test tube and add just enough concentrated sulfuric acid to cover the salt Warm if necessary to evolve the gas. EQUATION;

Very cautiously smell by fanning the gas toward you with your hand. Result?

Insert the moistened end of a glass rod into the hydrogen chlo-

<sup>•</sup> To obtain blue litmus paper from red litmus paper, hold the paper in the mouth of the ammonium hydroxide bottle. Blue litmus paper will change to red in the mouth of the hydrochloric acid bottle.

ride gas. Remove and touch the end of the glass rod to a piece of blue litmus paper. Result?

This solution is hydrochloric acid.

(e) ACTION ON A METAL: Pour a few milliliters of dilute\* hydrochloric acid on about I cm. strip of magnessum ribbon contained in a test tube. Loosely close the mouth of the test tube with your thumb to collect and prevent the escape of the gas formed. In about a minute, remove your thumb and quickly bring the mouth of the

test tube to a flame. Result?

This gas is hydrogen. What replaced the hydrogen in the acid?

(f) ACTION ON OXIDES OF METALS: Barely cover the bottom of a test tube with copper oxide Add 3 ml of concentrated HCl. Carefully heat to boiling, and then fill the test tube with water.

What evidence is there that a chemical action took place?

Complete the following equation:

- (g) Action on Hydroxides See Exercise 15.
- (h) ACTION ON CARBONATES: Try the action of a few drops of any acid such as dilute hydrochloric acid upon a pinch of any car-

bonate, as sodium carbonate. Result?

(i) Summarize the characteristic properties of water solutions of acids, keeping in mind the typical acid, hydrochloric acid.

<sup>\*</sup> Dilute and solutions for laboratory use may be made by adding one part of acid to approximately four parts of water.

# EXERCISE 14-CHAPTER VII TESTS FOR NONMETALLIC IONS

Section Date Name

MATERIALS Sodium corbonate, solutions of silver nitrale, forrum chloride, ferrous sulfate (enturated), potassium bromide, potassium iodide, ammonium molybdate, ammonium oxialte, disodium hydrogen phosphate, calcium chloride, and Rochelle solts. Chloroform, chlorine water (prepare chlorine water by pouring a few drops of hydrochloric acid on two or three crystals of potassium chloride in a test tube. Then when the test tube is filled with green chlorine gas, fill the test tube one fourth full of water, close with the tumb, and shake (1).

The following tests are to stimulate an interest in qualitative analysis, and to develop certain technics:

- (a) CHLORIDE: To 5 ml. of dulute hydrochloric acid in a test tube add sufficient silver nitrate solution to produce a heavy precipitate. Shake the mixture to coagulate the particles of silver chloride. When most of the precipitate has settled pour off the liquid above it, nearly fill the test tube with water, shake, and allow the precipitate to settle. Pour off the liquid as before and divide the precipitate countly among three test tubes.
- To one portion add dilute nitric acid, and record whether the precipitate is soluble.
- 2. To the second portion add dilute ammonium hydroxide; shake the tube and record whether soluble
- The third portion when placed in a bright light, preferably sunlight for several minutes, turns

(b) SULFATE: To 5 ml. of dilute sulfuric acid in a test tube add barrum chloride solution. The solid which separates is barium

sulfate. Test its solubility in dilute HCl Result?

(c) NITRATE: Pour into a test tube 3 ml. of saturated solution of ferrous sulfate. Add to it an equal quantity of very dilute nitric acid (5 drops of concentrated acid in 10 ml. of H<sub>2</sub>O). When the two solutions have been thoroughly mixed, incline the test tube and carefully pour in 3 ml. of concentrated H<sub>2</sub>SO<sub>4</sub> in such a manner that the acid forms a separate layer. The brown coloration between the two layers of liquid constitutes the ring test for a nitrate.

- (d) Browide: To a solution of potassium bromide add about 1 ml of chloroform and then a few drops of chlorine water.\* Place your thumb over the end of the test tube and shake vigorously. What is the color of the chloroform laver?
- (e) IODIDE: Repeat the bromide test, using a solution of potassium iodide instead of potassium bromide. What is the color of the chloroform layer?
- (f) PHOSPHATE: Add several drops of a solution of ammonium molybdate and a like amount of concentrated nitric acid to a solution of disodium hydrogen phosphate. Warm and allow to stand. What is the color of the precipitate?
- (g) CARBONATE. Dissolve a punch of sodium carbonate in 10 ml. of water. Have a drop of limewater ready on the end of a glass tube, add a few drops of dilute hydrochloric acid, and immediately, while the action is going on, hold the end of the glass tube just above the solution for a short time. Examine the limewater carefully in a bright light What do you observe?
- (h) OXALATE Add a few drops of calcium chloride solution to an ammonium oxalate solution What result do you obtain?
- (t) TARTRATE: To a solution of Rochelle salt, add several drops of silver nitrate solution. Result?

Add dilute ammonium hydroxide a drop at a time, shaking after each addition, until the precipitate is nearly all dissolved. If the precipitate dissolves, a drop or two of silver nitrate solution will reproduce the precipitate. Warm the solution. What is produced on the sides of the test tube?

Instruction: Clean test tube used in (i) with a few drops of nitric acid.

<sup>\*</sup>If not provided on supply table refer to materials for method of preparing your chloring water.

## SUMMARY

Negative Ions	Reagent Added	Result
Chloride		1
Sulfate		
Nitrate		
3romide		
odide		
Phosphate		
Carbonate		
Oxalate		
l'artrate		

If time permits, identify the acid radical in an unknown com-

pound.

# EXERCISE 15—CHAPTER VIII BASES

Section Date Name

MATERIALS Dilute solutions of copper sulfate, ferric chloride, and magnesium sulfate sodium, lime (calcium oxide), litmus paper, I per cent phenol-phthalen solution in alcohol

(a) PROPERTIES Place separately in test tubes 5 ml portions of very dilute sodium hydroxide solution, very dilute ammonium hydroxide, and calcium hydroxide solution Drop red litmus paper in each solution Result?

Taste a drop of each solution. Result?

Write the formulas of the bases

In what respects are they similar in composition?

Pour 5 ml of sodium hydroxide solution in a test tube containing an equal quantity of a dilute acid, as hydrochloric acid. Feel the test tube. Is there an evidence of chemical action?

(b) ACTION OF ACTIVE METALS ON WATER: Remove the oil from a piece of sodium about as large as a grain of rice by pressing between filter papers Throw it into an evaporating dish half full of water. Watch the action through a piece of glass or by standing at some distance to avoid being hit by the spattering drops. Consider that sodium displaces only one-half the hydrogen in water and complete the equation.

When active metals like sodium react with water what gas is liberated?

When the action is over describe the sensation of touch that a soluble hydroxide produces between your thumb and fingers Touch a finger to the tongue. Neglecting the oily taste, what is its taste? What is the effect of the solution

on pieces of red and blue litmus paper?

Add a few drops of phenolphthalein solution. What happens?

The substance contained in the water is sodium hydroxide. It is a typical strong base or alkali

Summarize the characteristic properties of bases as observed in (a) and (b).

(c) ACTION OF THE OXIDES OF SOME METALS ON WATER: Place a piece of fresh lime as big as a marble in a small beaker and pour upon it about 5 ml of water. What happens after it has stood about

## ten minutes?

The substance so formed is calcium hydroxide. It is commonly called slaked lime, and is much used by masons and plasterers Write an equation, showing how calcium hydroxide is formed from calcium oxide and water.

(d) Insoluble Bases by Precipitation, Place 2 ml of copper sulfate, ferric chloride, and magnesium sulfate solutions in separate test tubes and dilute each with water to 10 ml. Add a few drops of sodium hydroxide solution to each solution and note the precipitation of the insoluble bases, Cu(OH)2, Fe(OH)3, and Mg(OH)2. Write equations for their formation.

Insoluble bases have no taste and no effect on the fingers or on indicators that is appreciable They react with acids, however, just as soluble bases do.

Date

analysis, and develop certain technics.

operation several times

Section

or wire, lancet

# EXERCISE 16—CHAPTER VIII TESTS FOR METALLIC ELEMENTS (ELECTROPOSITIVE IONS)

Name

The following tests are to stimulate an interest in qualitative

(a) Clean the wire by repeatedly dipping the end in concentrated hydrochloric acid and heating in the flame until the end of the wire imparts no color to the flame. It may be necessary to repeat this

1. Flame Tests: (These may be demonstrated.)

MATERIALS Solutions of sodium chloride, potassium chloride, calcium chloride, copper chloride, mercurous nitrate, mercuric nitrate, ferric chloride, magnesium sulfate, ammonium oxalate, silver nitrate, potassium sulfocyanate, ammonium chloride, disodium hydroen phosphate platinum wire, copper chins

•		
(b) In making a test the salt solution, and he		of the wire to a drop of zing part) of the flame.
(c) Place a drop of e		of sodium, potassium,
(d) Make the flame before and test salts or results		n salt. Clean the wire as n, and copper. Record
Solution	Formula	Color of Flame
1 Sodium chloride		
2 Potassium chloride		
3 Calcium chloride		
4 Cupric chloride		

2. COLOR AND PRECIPITATION TESTS: Use approximately 2 ml of the solutions of the following metallic salts, e. g., take 2 ml. of a

solution of a mercurous compound to make the test for mercurous mercury.

(a) Mercurous Salts. Upon addition of dilute hydrochloric acid

a precipitate forms which turns upon addition of sufficient ammonium hydroxide. Calomel is mercurous chloride. Will hydrochloric acid produce a precipitate with a mercuric salt solution? Mercuric chloride is commonly called bichloride of mercury or corrosive sublimate.

Bichloride of mercury as compared to calomel is in water.

(b) Mercuric Salts: Drop a clean chip or a piece of copper into either the mercurous or mercuric salt solution. It will become silvered in a short time.

- (c) Iron Salts: A few drops of potassium sulfocyanate solution added to 5 ml. of any ferric salt solution produces a color. If a ferrous salt is used it must be oxidized by boiling with a few cubic centimeters of mitric acid before making the test Boil gently 2 ml. of nitric acid containing one drop of blood until a light yellow color is produced. Cool and dilute with an equal volume of water. Make the test for iron Do you find iron in the blood?
- (d) Copper Salts. Ammonium hydroxide added to a cupric salt solution forms a light blue precipitate which dissolves in an excess of the reagent to produce a colored solution The flame test for copper is
- (e) Magnesium Salts: Add a clear mixture of 1 ml each of ammonium chloride, ammonium hydroxide, and disodium hydrogen phosphate solutions to 5 ml. of a magnesium salt solution. Allow to stand for several minutes What is the color of the precipitate

that forms on the inside of the test tube?

compound

If calcium as well as magnesium is present in urme, the calcium must first be removed by the method in (f).

- (f) Calcium Salts: Ammonium oxalate solution added to a calcium salt solution produces a precipitate. By the flame test, the color of calcium compounds is
- (g) Silver Salts: Dulute hydrochloric acid added to a silver salt solution produces a precipitate, which (upon vigorous shaking) in ammonium hydroxide

  If time permits, identify and record the metal found in an unknown

# EXERCISE 17—CHAPTER VIII HYDROGEN ION-HYDROXYL ION CONCENTRATION

Section Date Name

MATERIALS Alkacud or Nitrazine test papers solutions of material available as listed under A (c) N/10 HCl urine buffer mixture (Sorensen s pH 698 made by mixing 60 ml M/15 Na<sub>2</sub>HPO<sub>4</sub> anhydrous 9 473 Gm per liter with 40 ml M/15 KH<sub>2</sub>PO<sub>2</sub> 9 078 Gm per liter)

#### Instruction

The principle of making hydrogen ion concentration (pH) measure ments in terms of their pH notations is based on the fact that various chemical substances, known as "indicators" change color when they are acted on by solutions of different acidities or alkalinities. Test uppers carrying a mixture of several indicators that are more sensitive than litmus are simple and inexpensive methods of making approximate pH determinations. Alkacid test paper made by Fisher Scientific Company makes pH measurement of funds within a range of pH 20 to pH 100 with an accuracy of ±1pH, while Nitrazine test paper, made by E R Squibb and Sons, has a range of colors for pH 45 to 75 by half units. The Nitrazine is more accurate for acid determinations, but the Alkacid has a wider range. The use of both papers requires the same method of procedure.

## A TEST PAPER METHOD (APPROXIMATE\* pH)

- (a) METROD OF PROCEDURE Dip a clean glass rod into the solution to be measured and transfer a drop to the surface of the paper, spreading it evenly by stroking At the end of a minute compare the color produced with the standard color chart showing the various pH values (found on the container of the test papers)
- (b) ALTERNATE METHOD OF PROCEDURE Dip paper into the solution three consecutive times and then shake off the excess inquid At the end of a minute compare color of paper with colors on chart

<sup>\*</sup>The accuracy of colormetric methods is affected by salts proteins colloids term perature confidence from the first buffered solutions—any one of which produces specific errors of 0.5 pH units or more For great accuracy electrometric methods are used

(c) DETERMINATIONS AND TABULATION: Determine and record in the table the pH values of the solutions and physiological material available.

Material to be Tested	Approximate Values	pH Values Found
Human blood plasma	73-75	
Adult gastric contents	09-16	
Saliva.	60-76	
Urine (human)	48-80	
Milk, cow's	6 2-7 3	
Milk of magnesia	10 5	

# B. BUFFER ACTION

A number of substances exert what is known as buffer action. This means that considerable amounts of acid or alkali can be added to solutions of these substances, or that the solutions can be diluted, with only a relatively small change in the pH values.

(a) EFFECT OF A BUFFER ON pH MEASUREMENTS: To 10 ml. of distilled water which has a pH of about 60, add one drop of N/10 HCl. What is the approximate change in pH value?

Now to 10 ml. of buffer mixture pH 7.0, add one drop N/10 HCl.

What, if any, is the change in pH value?

Add  $\dot{N}/10$  HCl drop by drop until a definite change in pH value is obtained.

Add a drop of N/10 HCl to a specimen of urine. Is the change in pH value greater than the change with the buffer mixture? Is the change as great as the change in water alone?

(b) EFFECT OF DILUTION ON pH VALUES: Dilute a buffer mixture and a specimen of urine with the same amount of water. Make pH determinations of each solution

What is the degree of dilution necessary to cause a change in pH value?

# EXERCISE 18—CHAPTER IX NEUTRALIZATION: HYDROLYSIS

Section

Date

Name

MATERIALS Sodium hydrogen carbonate, phenolphthalein indicator, sodium carbonate, ammonium chloride, blue litmus paper

#### A. NEUTRALIZATION

(a) The mixing of a base and an acid solution in the exact quantities for complete reaction with each other is called neutralization and the products formed are salt and water. How could you determine by means of htmus paper whether a solution was exactly neutral?

(b) Dulute about 2 ml. of soduum hydroxide solution with an equal volume of water. To this solution in an evaporating dish add a few drops of dilute hydrochloric acid and one small piece of litmus paper. Stir the resulting solution with a glass rod and continue to add the acid drop by drop until the resulting solution is neutral, e. e, a drop of acid or base will cause the piece of litmus paper to change color, or is at most very slightly acid. Considering that the characteristic properties of an acid are due to the hydrogen ions, H<sup>+</sup>, and those of a base due to the hydroxyl ions, OH<sup>-</sup>, then if the solution is neutral, that is, neither acid nor basic, what new undis-

sociated molecule is always formed in neutralization? Remove the litmus paper and drop it into the waste jar, not in the sink

Evaporate the solution to dryness Taste the residue. Result?

# What is it?

What is the name given to any compound formed by the interaction of any acid and any base?

Complete the following ionic equation, showing that an ionized salt and undissociated water are formed in neutralization

#### B. HYDROLYSIS OF SALTS

(a) A salt formed from a strong base and a weak acid. Dissolve about 1 gram (curved portion of test tube) of sodium hydrogen carbonate (baking soda) in half a test tube of water.

Add to this solution one drop of phenolphthalein indicator. Is the solution acid or alkaline?

In hydrolysis both a base and an acid are formed, one of which may be stronger than the other. Why is this solution alkaline?

How do you account for the bitter taste sometimes present in baked biscuits and cakes?

Set aside the pink solution for comparison with (b).

(b) Heat approximately the same weight (1 Gm) of dry sodium hydrogen carbonate in an evaporating dish with an occasional stirring for ten minutes.

Cool and dissolve this residue in half a test tube of water.

Add one drop of the indicator and compare the depth of color with that obtained with (a).

Which compound, the NaHCO<sub>3</sub> or the heated NaHCO<sub>3</sub>, that is the Na<sub>2</sub>CO<sub>3</sub>, hydrolyzes the more?

Dissolve in one-half test tube of water approximately the same weight (I Gm) of sodium carbonate (washing soda) obtained from the supply table, and compare the taste of this solution with the taste of the solution of salt just prepared from the heated sodium hydrogen carbonate. Result? State the household name of the compound formed by heating haking soda

(c) A salt formed from a weak base and a strong acid Dissolve a few crystals of ammonium chloride in half a test tube of water Insert a piece of blue litmus paper. Remove the litmus paper The color of the litmus paper indicates that this salt, ammonium chloride, forms an

NH4CI+HOH⇔NH4OH+ ... ...

The results from (a), and (b), and (c) indicate that some salts in solution give acid or alkaline reactions. This is a special type of reaction involving water, called hydrolysts, and is the result of a reaction between the salt and water with the formation of an acid and a base, one of which is more dissociated than the other. When equations of hydrolysis are read in reverse they become examples of

CaCl<sub>2</sub> + \_ HOH ⇌ \_ - + \_ \_ (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> + \_ HOH ⇌ \_ + \_ \_ Al<sub>2</sub>S<sub>2</sub> + \_ 6 HOH ⇌ \_ + \_ \_ Na<sub>3</sub>PO<sub>4</sub> + \_ HOH ⇌ \_ - + \_ \_ \_

Considering that natural water contains some calcium chloride what effect will such waters have in iron pipes or boilers?

# EXERCISE 19—CHAPTER IX METHODS OF PREPARING SALTS

Section Date Name

MATERIALS Sodium hydrogen carbonate, quinine, solutions of lead acetate sodium sulfate, magnesium sulfate, quinine sulfate (1500), tea coffee, tannic acid, picric acid, iodine (in KI), potassium permanganate, phenolphthalein Optional solutions will be found on p 692

## A. SOME METHODS OF PREPARING SALTS

(a) DIRECT COMBINATION Recall the second experiment of iron and sulfur in Exercise 2 Write the equation

Farrous sulfid

(b) NEUTRALIZATION. Recall the experiment just performed in this chapter on neutralization. Write the equation

+ \_\_ → \_\_ +

(c) PRECIPITATION \* To a test tube containing a few milliliters of lead acetate solution, add sufficient sodium sulfate solution to produce a precipitate Considering that all sodium salts are soluble, name the precipitate formed

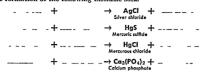
Pb<sup>++</sup>, 2C<sub>2</sub>H<sub>3</sub>O<sub>2</sub><sup>-</sup> + 2Na<sup>+</sup>, 5O<sub>4</sub><sup>-</sup> → , , , ↓ + 2 Na<sup>+</sup>C<sub>2</sub>H<sub>3</sub>O<sub>2</sub><sup>-</sup> Sod um positite

Could Epsom salts  $(Mg^{++}SO_4^-)$  be used instead of sodium sulfate (Glauber's salt) to precipitate the lead ion?

In the preparation of an insoluble salt from the action of two soluble salts, how can the soluble salt formed be recovered?

<sup>•</sup> This experiment is to arouse an interest in constructive work, familiarize the student with the solubility table and to show the practical value of knowing how to form in soluble compounds. For instance some poisonous compounds may be rendered harm less by changing them over into insoluble compounds.

Consult the solubility table, p. 778, and select soluble salts for the formation of the following unsoluble salts



(d) Volatility: Cover the bottom of a test tube with baking soda and add dilute hydrochloric acid drop by drop until you can see that no more gas is being evolved. Evaporate and taste the residue. What is it?

(e) GENERAL METHODS OF PREPARING SOLUBLE SALTS: Write equations for the action of an acid upon a metal, a metallic oxide. a hydroxide, and a carbonate.

Metal	+ -	→	_ +
Oxide	+	>	+
Hydroxide	+	→ .	+
Carbonate	<b>→</b>	_ +	4

# B. ALKALOIDS

(a) Solubility: To a very small amount, the size of a pinhead, of quinine alkaloid (not the salt) in a test tube add a few millulters of water. Agitate it. Is it soluble? Now add a drop

of sulfuric acid. Warm and agitate it Result?

Alkaloids combine with acids to form salts Considering this, which are water soluble, the pure alkaloids or the alkaloid salts?

(b) TASTE: Taste a few drops of the quinine sulfate. Result?

(c) REACTION: Into a test tube containing about 5	ml of dis-
tilled water, add a small amount (size of grain of rice)	
alkaloid (not the salt). Shake the tube thoroughly and	test with a
drop of phenolphthalein solution Look down through	ı the lıquid
in the test tube. Any color change?	What does

this indicate concerning the nature of an alkaloid?

(d) Summarize the common characteristic properties of alkaloids, using quinine as an example

(e) PRECIPITANTS: Into test tubes, each containing about 5 ml of quinine sulfate solution, add separately one or more drops of tea, coffee, tamic acid, picne acid, iodine, and potassium permanganate solutions Record results in the following table

Solutions of	Action on Alkaloid
Tea	
Coffee	
Tannic acid	
Picrie acid	
Iodine	
Potassium permanganate*	

<sup>\*</sup>Potassium permanganate (KMnO4) oxidizes the alkaloid to a harmless compound

Why can tea be used as an antidote in alkaloid poisoning?

If so directed by the Instructor test and record the action of the following "alkaloidal reagents" on 5 ml. portions of quinine sulfate solution

Solutions of	Action on Alkaloid
Potassium mercuric iodide (Mayer's reagent)	
Phosphomolybdic acid	
Phosphotungstic acid	

# EXERCISE 20-CHAPTER X

Section

Date Name

MATERIALS. Ammonium sulfate, slaked lime, ammonium chloride

(a) Place a pinch of ammonium sulfate in the hand and smell. Smell a pinch of dry, slaked lime, Ca(OH)<sub>2</sub>. Rub the two together in the palm of the hand. Smell. Result?

Bring a moistened strip of red litmus paper near the mixture Result?

Indicates what?

- (b) Repeat (a), using ammonium chloride and slaked lime, Ca(OH)<sub>2</sub>. Results?
- (c) Heat gently in a test tube a small amount of ammonium chloride with any strong hydroxide solution, as sodium hydroxide. Smell. Result?

How may you prove that any substance given you is or is not an ammonium salt?

(d) What kind of a substance have you used each time to free ammonia from ammonium compounds? What general method of preparing ammonia is indicated by these

What general method of preparing ammonia is indicated by these experiments?

(e) What is the odor of ammonia?
Is it heavier or lighter than air?

(f) To a test tube one	thurd	full of water add one drop	of dilute
ammonium hydroxide (1	5)	Heat to boiling and smell	Result?

Continue the boiling for several minutes (five) Smell What must have happened to the compound dissolved in the water?

How does heat affect its solubility in water?

What do you conclude about the stability of ammonium hydroxide?

(g) Tabulate the differences between ammonia and ammonium

	Ammonia	Ammonium
Formula		
Free or combined		
Gas or radical		
Exists in water as		

If time permits, obtain an unknown substance from the In structor and test it to determine if it is an ammonium salt

# EXERCISE 21-CHAPTER X CHLORINE

Section

Date

Name
MATERIAL Potassium chlorate

To a few crystals of potassium chlorate in a dry test tube add several drops of concentrated hydrochloric acid.

- (a) The color of the gas (chlorine) formed is
- (b) Cautiously smell Result?
- (c) Hold a piece of dry red litmus paper and a piece of moist red litmus paper in the mouth of the test tube for a few seconds only.

What happened to the moist red litmus paper?

$$H_2O + Cl_2 \rightarrow H^+Cl^- +$$

hypochlorous  $\downarrow$  acid

 $HCl + -$ 

 $\operatorname{Hold}$  a piece of moist blue litmus paper in the mouth of the test tube of chlorine gas

The first color change in the blue litmus is due to the presence of what ions?

The second change in color is due to

(d) Half fill the test tube with water, close the mouth with your thumb, and shake. Make an ink spot on a piece of paper and im-

merse in the liquid Allow to stand. Result?
What practical application can be made of this kind of a solution?

### EXERCISE 22-CHAPTER X

Section Date Name

MATERIALS Potassium vodide, manganese dioxide, dilute sulfuric acid (two to one), ethyl alcohol, I per cent cooked starch solution, dilute (5 per cent) sodium throsulfate solution

- (a) PREPARATION: Into a dry test tube add I Gm. (curved portion of the bottom of a test tube) of powdered potassium iodide and an equal bulk of manganese dioride. Mix carefully so that none will adhere to the side of the test tube Now add 3 ml. of dilute sulfuric acid (two parts of acid to one part of water). Holding the test tube at an angle, warm the lower end of the tube very gently. The upper end of the test tube must be kept as cool as possible if iodine crystals are to be formed by condensation. Note the vapor of the iodine and the grayish black crystals which deposit near the mouth of the tube I f the iodine starts to vaporize and escape from the test tube, hold an inverted test tube against the mouth of the heated test tube in order to condense and collect crystals of iodine.
- (6) PROPERTES: Using a wood splint or a glass rod, scrape out some of the crystals in the inside of the tube. Using about the same number of crystals in each case, test the solubility of iodine in the same amount (2 ml) of water, alcohol, and a solution of potassium iodide in water. Reserve these solutions.

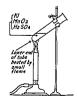


Fig 2

What name is given in pharmacy to the alcoholic solution of iodine just prepared?

How could you remove an excess of rodine from the skin?

Solvent (2 ml )	Color of Solution	Degree of Solubility (slightly, moderately or very)
Water		
Alcohol		
Potassium iodide solution		

(c) REMOVAL OF IODINE STAIN: Divide the alcoholic iodine solution into two parts. To one add a few drops of ammonium hydroxide and to the other sodium thiosulfate solution. Result?

In both cases the iodune is changed into a colorless iodine solution. Either of the two procedures may be used in removing iodine stains from clothes.

(d) STARCH TEST FOR FREE IODINE. Add a drop of iodine in potassium iodide solution to a few ml. of dilute starch solution.

What color is produced?

What difficulty might be met with m attempting to remove iodine from starched cloth by the use of ammonium hydroxide or sodium thiosulfate solution?

# EXERCISE 23-CHAPTER X PROPERTIES OF CARBON

Section Date Name

MATERIALS Litmus solution, powdered copper oxide, limewater, powdered wood and animal charcoal

(a) DECOLORIZER. Dilute some blue litmus solution in a test tube with enough water to give it a light color. To one-half of this solution in another test tube, add about 3 ml of animal charcoal, shake, warm carefully two minutes and filter. Compare the color with that of the original solution. What happened to the

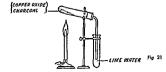
#### litmus?

The coloring matters in vinegar, raw sugar, indigo, etc., belong to the same class of matter as litmus (colloidal substances), and these are removed by animal charcoal.

(b) DEODORIZER: Half fill a test tube with water and add enough ammonium hydroxide (two or three drops) to give a marked odor of ammonia. Next fill approximately half of the remaining space in the test tube with dry ammal charcoal. Close the mouth of the tube with your thumb and shake thoroughly for two minutes

Smell. Is the odor as strong as the original solution?

(c) REDUCING AGENT Mix thoroughly 2 Gm. of powdered copper oxide with an equal amount of wood charcoal in a test tube. Fit the test tube with a delivery tube extending into a test tube



half filled with hmewater. Heat for ten minutes What has happened to the limewater?

### Explain

Empty the contents of the test tube on a paper upon the desk What is the reddish brown material?

To what process has the copper oxide been subjected?

What happened to some of the charcoal?

The above equation shows that carbon is a agent.

What kind of an agent is copper oxide?

Whenever there is reduction there simultaneously has to be

State three properties of carbon

## EXERCISE 24—CHAPTER X CHANGES IN AIR CAUSED BY RESPIRATION

Section Date Name

MATERIALS Deflagrating spoon, birthday candles, string or rubber band

Fill three bottles with water and invert them over water in trough.

(a) Using a glass tube, a rubber tube, or both, displace the water in one bottle with beginning expired air. Slip a glass plate under the mouth of the bottle, and stand it in an upright position on the table.

(b) Displace the water in the second bottle with air from the end of expirations, that is the last portions of air expelled from the lungs. Cover with a glass plate and stand right side up on the table.

(c) Take a big breath of air and hold it in the lungs for half a minute, if possible, and then displace the water in the third bottle with the beginning expired air

(d) Fasten a candle to a deflagrating spoon with a rubber band or string Light the candle, slip aside the cover glass on the first bottle, and lower the burning candle. In a similar way, test the air in the other two bottles. From the behavior of the candle flame in the first and second bottles, what conclusion may be drawn concerning the amount of oxygen in the last portions of ordinary expired air?

Why is this so?

How do the first portions of expired air held in the lungs for half a minute compare in oxygen content with the end portions of ordinary

expired air?

What is the effect of deep respiration upon the percentage of oxygen in the expired air?

What is the effect of deep respiration upon the percentage of carbon dioxide in the expired au?

(e) What is the function of carbon dioxide in the oxygen-carbon dioxide mixture used in suffocation, collapse, or recovery from anesthesia?

# EXERCISE 25-CHAPTER XII DESTRUCTIVE DISTILLATION

Section Date Name

MATERIALS Lead acetate solution, wood splints, soft coal, five-inch test tube with side arm and connection c (Fig 22)

#### A. DESTRUCTIVE DISTILLATION OF WOOD

 Break six or seven wood splints in the middle and place in the lower part of the test tube Set up apparatus according to accompanying figure, with mouth of test tube slightly lower than the other end. Why?

Heat gently at first and then strongly until no further change is noted. During the heating, occasionally bring a flame to the edge of the jet tube. Result?

Is the flame luminous?



Test the liquid in the test tube (b) with blue litmus paper.

Result?

What name is given to the substance that causes this change?

3 What other liquids are present in the test tube (b)?

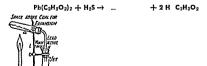
- 4 Remove, examine, and name the residue left in the glass test tube (a)
- 5 What three main commercial products are obtained by the destructive distillation of wood?
  - 6 State an important use of each product formed

#### B DESTRUCTIVE DISTILLATION OF SOFT COAL

- 1 Fill a glass test tube (same one used in A), one half full of coarsely ground soft coal, forming a layer on the lower side of the test tube This allows space above the coal for expansion Place a piece of filter paper moistened with lead acetate solution on the inside of the test tube (b), Fig 23, the end projecting from the mouth of the tube so that it will be held in position by the stopper when inserted Heat gently at first and then strongly until no further change is noted
  - 2 Test the gas at the end of the jet with a flame Result?

Does it act similar to illuminating gas?

3 What compound is formed on the filter paper, considering that hydrogen sulfide is in the gas?



4. What liquid collects in the test tube (b)?

Remove the stopper from the tube (b), add about as much sodium hydroxide solution as there is liquid in the tube, warm gently and at the same time hold a piece of moistened red litmus paper at the mouth of the tube Considering that the coal contains nitrogen, what volatile gas formed would turn moist red litmus paper to a blue color?

- 5 What is the residue left in test tube (a)?
- What main products are obtained by the destructive distillation of soft coal?

Are the substances identified of importance commercially? State an important use of each product formed

### EXERCISE 26—CHAPTER XII COMPOSITION OF MOST ORGANIC COMPOUNDS

Section Date Name

MATERIALS Dry egg albumin, casein, powdered copper oxide, soda lime, sodium, solution of lead acetate, ammonium molybdate solution, granular copper oxide. solution chloride

For optional methods Five-inch small bore glass tubing, powdered copper oxide, sugar, soda lime (CaO + NaOH), lerrous sulfate solution containing a trace of ferric chloride, sodium nitroprusside solution (fresh), platinum wire

### Instruction:

Carbon, hydrogen, and oxygen with occasional smaller amounts of nitrogen, halogens, sulfur, and phosphorus are the chief elements found in organic compounds.

(a) CARBON AND HYDROGEN Organic compounds are frequently flammable, and when heated take fire or char. Carbon and hydrogen are detected by oxidation

 Heat a very small amount of dry egg albumin (or casein) in a test tube held in an inclined position. What does the change in color of the organic compound indicate?

What collects in the upper and cooler portion of the test tube?

Continue the heating until there is no further

change. The charring indicates the presence of while the formation of water indicates the presence of

Complete oxidation of organic compounds releases energy and forms what two main products?

2. Optonal: A more delicate test for carbon is to heat the substance with some easily reducible metallic oxide, the oxygen of which unites with the carbon to form carbon dioxide. The presence of the carbon dioxide may be shown by passing the gas through Immewater. Hydrogen is at the same time oxidized into water, which condenses on the cold part of the apparatus.

Take a piece of a small bore soft glass tube about five inches long and fuse it together at one end Mix in a mortar a pinch of fine copper oxide with about one-tenth of its bulk of powdered sugar. Pour the mixture into the tube and bend it so as to form a right angle. Let the open end dip into limewater contained in a test tube (Fig. 24). Heat the mixture gently with a small flame. The



gas which bubbles through the limewater turns the limewater
thereby indicating that carbon was oxidized

to , which reacted with the limewater to
form . Moisture soon appears on the sides

of the tube. Considering that the oxygen came from the copper oxide, the formation of water indicates the presence of

in the compound.

Gases or volatile substances like ether and alcohol cannot, of course, be examined in this way, but the gases or liquids may be burned in a closed vessel, or the vapor led over a layer of red-hot copper oxide and then through limewater.

- (b) NITROGEN: Organic compounds containing nitrogen evolve ammonia upon being heated with soda lime.
- Mix thoroughly a small amount of dry egg albumin (or casein)
  with an equal bulk of soda lime Place in a dry test tube and heat,
  at the same time holding a piece of moistened red litmus paper at
  the mouth of the tube. The formation of a blue color shows that
  the gas evolved, which forms a base with the moisture, must be

Optional: When nitrogenous organic compounds are heated with metallic sodium, sodium cyanide is formed, and the subsequent test is the same as for a cyanide.

Pour about 10 ml. of water in a beaker. Place a fragment of gelatin or cheese in a small, dry test tube along with a piece of metallic sodium the size of a grain of rice. Hold the test tube horizontal and heat the lower end at first gently, until the reaction subsides, and then strongly, until the glass is nearly red-hot. At this stage the carbon will have been mostly burned out of the nitrogenous substance, leaving a white to grayish ash in the test tube.

At arms' length (warning) place the hot end of the tube in the beaker containing 10 ml. of water. The glass crumbles away, and any residual sodium is decomposed with a bright flash; all the cyanide rapidly goes into solution, while a small quantity of carbon remains suspended in the liquid. Filter into a test tube. Pour into the clear solution about 1 ml. of ferrous sulfate solution to which a drop of ferric chloride has been added, boil for a minute, cool, and acidify carefully with a few drops of dilute hydrochloric

acid. A colored precipitate indicates the presence of nutrogen.

- (c) SULFUR: Loosely combined sulfur after being boiled with sodium hydroxide forms sodium sulfide, which gives a black precipitate with lead acetate solution.
- To 2 ml. of dilute sodium hydroxide in a test tube add a very small amount of egg albumin (or casein), and heat for a minute or more, cool the test tube in running water, and then add a few drops
- of lead acetate solution. The formation of insoluble lead sulfide inducates the presence of sulfur. Repeat the experiment with hair,
- Optional: Sulfur (loosely combined): The presence of sulfur in organic compounds may be detected by heating the substance with metallic sodium. The alkaline sulfide, when dissolved in water, gives a violet coloration with a solution of sodium nitropruside.

Heat a fragment of egg albumin with a piece of sodium in a dry test tube until the bottom of the tube is red-hot, and place it in about 10 ml. of water in a beaker of water. Filter the liquid and add a few drops of sodium nitroprusside solution. What is the color? (d) Phosphorus: Upon oxidation, phosphorus changes to a phosphate, which with ammonium molybdate produces a yellow precipitate.

To a small amount of casein in a test tube add approximately 1 ml. each of concentrated nitric and sulfuric acids. Boil carefully until the solution becomes clear. Cool thoroughly, and then add slowly about as much cold water as you have liquid in the tube. Add a small amount of ammonium molybdate solution and warm

carefully. A precipitate indicates the presence of phosphorus. If a colored precipitate does not form, try the technic tor a phosphate on page 677.

(e) HALOGENS: Many halogen compounds impart a green fringe to the outer mantle of the nonluminous flame. A more delicate test is to heat the substance with copper oxide, which gives a vivid green coloration.

Heat a fragment of granular copper oxide, held in the loop of a platinum wire, in the outer mantle of the nonluminous flame until it ceases to color the flame green. Let it cool down a little and then dust on some halogen compound. Now heat again. A bright flame, accompanied by a blue zone immediately around the oxide, indicates the presence of a halogen.

(f) OXYGEN: There are no satisfactory direct tests for oxygen, and it is almost invariably calculated by difference.

# EXERCISE 27—CHAPTER XII SATURATED AND UNSATURATED OPEN-CHAIN HYDROCAPRONS

Section

Date

Name

MATERIALS: Fused sodium acetate, soda lime (sodium calcium hydrate), very dilute bromine uniter, 95 per cent athyl alcohol, calcium carbide, sidearm test tube, medicine dropper, corks, small cylinder of ethylene (if avuilable).

#### Instruction:

The aliphatic or open-chain hydrocarbons are (1) saturated compounds, that is, they contain not more than two shared electrons between their carbon atoms, or (2) unsaturated compounds with four or six electrons shared between their carbon atoms. In performing the following experiments on the saturated hydrocarbons (represented by methane) and the unsaturated hydrocarbons (represented by ethylene and acetylene) look for differences between them in the degree of explosiveness when mixed with air, in the color of their flames, and in the type of reaction with bromine, i. e., whether they form substitution or addition products. All hydrocarbons undergo oxidation.

With the consent of the Instructor, two students may work together on the following experiments. If time does not allow for completion of (a), (b), and (c), omit (b).

(a) METHANE Natural gas is approximately 90 per cent methane, and if available use it as a source of methane, otherwise make the methane as directed Using a dry test tube, set up apparatus as in Fig. 25. Have ready a stoppered test tube. Fill the generator one-half full with a mixture of one part fused solium acetate and two parts sode lime. Heat carefully, and after allowing some of the gas to escape, collect one half a test tube of methane gas. Lift the test tube from the water so that the water will run out of the test tube and air will runk in to mix with the methane. Close the mouth of the test tube with your thumb and bring the tube horizontally, to the side of a Bunsen burner flame. Remove your thumb.

#### Result?

Collect and stopper a test tube of methane. Remove the glass delivery tube from the water and ignite the escaping methane

Does the color of the flame indicate that carbon is being liberated,

i. e., produces a colored flame? Invert a clean, dry bottle for a few seconds over (not in) the Bunsen burner flame Observe the film of moisture on the inside of the bottle Add a few milhiliters of limewater to the bottle Close with a glass plate or rubber stooper and shake the bottle thoroughly. Result?

What are the products of complete combustion of hydrocarbons?

#### and

To the stoppered test tube of previously collected methane, add a few drops of bromine water. Restopper and shake the tube

vigorously. Does the bromine show any change in color?

No change in color of the bromine water indicates no reaction. Thrust a glass rod, previously dipped into ammonia water, into the test tube. A white cloud of ammonium bromide indicates the presence of HBr gas. Complete the reaction

Is this type of reaction of a halogen with a saturated hydrocarbon (represented by methane) one of substitution or of addition?

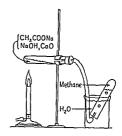


Fig 25—A Laboratory Method of Preparing Methane.

(b) ETHYLENE: (The laboratory preparation of ethylene is difficult and an inefficient process. If available collect two test tubes of pas from the ethylene cylinder on the supply table. Otherwise in groups of two or three make the ethylene as directed.) Use a dry sidearm test tube and a dry medicine dropper, the bulb of which must fit tightly. Set up an apparatus as in Fig. 26. Have ready two cork stoppered test tubes. Remove the rubber stopper containing the dry medicine dropper, and fill the dropper completely with ethyl alcohol. Place about 5 ml of concentrated sulfuric acid in the dry sidearm test tube, and with a very small flame carefully heat just to boiling. Replace the stopper and hold it in tightly during the collection of the ethylene, largely because of the danger of sulfuric acid spattering out of the tube when the alcohol falls on the hot acid. and by means of the medicine dropper, allow ethyl alcohol to fall, dron by drop, upon the hot sulfuric acid. Allow a few bubbles of gas to escape and then collect two test tubes of ethylene gas. In order to collect sufficient gas it may be necessary to keep the acid hot by gently heating it from time to time. If the experiment has to be repeated in order to collect more ethylene, remember that the generator tube must be dry before adding the concentrated sulfuric acid. Bring one tube of ethylene gas horizontally to the side of (not in) a Bunsen burner flame. Remove cork to ignite the gas.

Result?

How does the color of the ethylene flame compare with that of the methane flame?

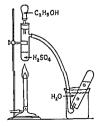


Fig 26—Noting Preparation of Ethylene

Add a few drops of bromine water to the second test tube of ethylene, stopper, and shake it vigorously. Result?

From the equation would you expect to prove the presence of HBr? The decoloration of bromine with ethylene and the failure to prove the presence of HBr indicate that ethylene is an compound

Is the dominant type of reaction of an unsaturated hydrocarbon (represented by ethylene) that of substitution or of addition?

Is the decoloration of bromine more rapid with saturated or unsaturated hydrocarbons?

Which type of hydrocarbon is the more reactive?

How many shared electrons are there between the carbon atoms of ethylene?

Complete the following equation for the preparation of ethylene:

Combustion of ethylene: C2H4 + .... O2 → ....+ ....

Conditions such as temperature, pressure, and concentration greatly modify reactions. Thus ethylene is produced by the dehydrating action of sulfuric acid on ethyl alcohol, but at a temperature lower than 150° C. and with an excess of ethyl alcohol, the product formed is mostly ethyl ether (diethyl oxide).

(c) ACETLENE Use the same apparatus, excepting the burner, as in the preparation of ethylene. Have ready a stoppered test tube. Fill the curved portion of the dry test tube generator with small lumps of calcium carbide, and, by means of the medicine dropper, allow water to fall, drop by drop, upon the carbide. Allow a few bubbles of gas to escape and then collect one-half a test tube of acetylene gas Lift the tube from the water and carry, mouth downward, to (not in) a flame Result?

The acetylene-oxygen mixture is one of the most dangerous gaseous explosive mixtures known.

Collect a test tube of acetylene and quckly bring the mouth of the test tube to the side of a fiame What element is liberated when

acetylene is incompletely burned? The color of the acetylene flame is characteristic of unsaturated compounds when burned in a limited supply of oxygen. In comparing the color of the flame of the three classes of hydrocarbons (methane, ethylene, acetylene) how does the unsaturated class differ from the saturated class (represented by methane) with respect to completeness of combustion?

Collect another test tube of acetylene, stopper, and shake vigorously with several drops of bromine water. Result?

The decolorization of bromine with acetylene gas, and the failure to prove the presence of HBr formation indicates that acetylene,

like ethylene, is an compound
Is the dominant type of reaction of an unsaturated compound (rep-

resented by acetylene) that of substitution or addition?

Is the decoloration of bromine more rapid with saturated or unsaturated hydrocarbons?

What does that indicate?

Is acetylene more active than

ethylene?

Complete	the	following	equations

Complete the following equations:						
Preparation of acetylene:	CaC <sub>2</sub> +	$H_2O \rightarrow C_2H_2$	+			
Combustion of acetylene:	C2H2+	02→	+			
Differences Between Three Classes of Hydrocarbons						
	Methane	Ethylene	Acetylene			
Aolecular formula						
raphic formula						
Class (based on number of shared electrons)						
Explodes with air (slight, moderate, very)						
Color of flame						
Dominant reaction (substitution or addition)						
Order of activity (1st, 2nd, 3rd)						

### EXERCISE 28—CHAPTERS XIII AND XIV ALCOHOL, ALDEHYDES, ORGANIC ACIDS, ESTERS, AND ETHER

Section Date Name

MATERIALS Thermometer, glass condensing tube, compressed yeast, Karo syrup, camphor, oil, iodine crystals, dilute potassium dichromate solution, ethyl alcohol, methyl alcohol, copper spiral to fit in a test tube. (Use three feet of No 14 copper wire At a distance of three inches from one end wind the wire about 15 times around a pencil into a close spiral until within eight inches of the opposite end. Push the longest end through the coil and twist together to form a bandle?

Resource solution (I per cent), suber nitrate solution, formaldehyde solution, Benedict's solution (17.3 Gm of copper sulfate, 173 Gm of solution citrate, and 100 Gm of anhydrous sodium carbonate, made up to one liter with distilled water. Add the copper sulfate dissolved in 100 ml of water slowly to about 800 cc of the other filtered jurgedients, and finally make up to a blier?

Tollen's solution (Add NH<sub>4</sub>OH to dilute AgNO<sub>3</sub> solution until the precipitate which first forms dissolves), Pasteur's sails (850 ml distilled water containing 2 Gm K<sub>2</sub>PO<sub>4</sub>, 0 2 Gm Ca<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub>, 0 2 Gm MgSO<sub>4</sub>, 10 Gm-(NH<sub>4</sub>)<sub>2</sub>C<sub>4</sub>H<sub>4</sub>O<sub>6</sub>)

Acetic acid, amyl alcohol, saturated methyl alcoholic solution of salicylic acid, butyric acid, amyl acetale, milk, ferric chloride solution (5 per cent)

#### A. ALCOHOL

NOTE To be started several days before the regular laboratory period by student or instructor. The laboratory prepared alcoholic solution contains small amounts of esters, aldehydes, and higher alcohols.

PREPARATION. Dissolve one eighth cake of yeast in a flask containing 150 ml. of water, 20 ml. of Karo syrup, and 9 ml of Pasteur's salts (for the yeast to feed on). Put in some warm place for several days. Decant the liquid into a flask leaving the sediment in the bottom of the fermentation flask. Save one half of a test tube for (c). Set up the apparatus similar to Fig 27. Use approximately 150 ml. of the fermented solution previously prepared, and shull 5 to 10 ml. at as low a temperature as possible. The liquid should barely summer, not boil. The temperature at which the

liquid begins to distill is . . . ° C. Save the undistilled portion for part C. Organic Acids

C<sub>6</sub>H<sub>12</sub>O<sub>6</sub> 
$$\rightarrow$$
 2 \_\_\_\_\_ + 2 CO:  
Sugar Ethyl olcohol

### (b) PROPERTIES: Record the odor and taste of the distillate

Apply a lighted match to a small portion in an evaporating dish, Result?

Oxidation of alcohol in the human body generates heat with the formation of two end products, namely and ...

In a test tube containing some of the distillate, test the solubility of some camphor or a drop of oil. Is the camphor or oil very soluble in cold alcohol?

In boiling alcohol?

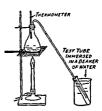


Fig. 27—Distillation Apparatus

(c) Test. To a few milliliters of the alcohol add a few iodine crystals and shake it until a dark brown color is produced. Add sodium hydroxide solution a drop at a time until the dark brown color changes to a deep yellow Iodoform separates as a yellow precipitate, and may be recognized by its odor. What is the principal use of iodoform?

#### B. ALDEHYDES

(a) To 1 ml. of ethyl alcohol (95 per cent) add a few drops of concentrated sulfuric acid and 1 ml. of the oxidizing agent, potassium dichromate solution. Warm gently to boiling and note the

sharp, penetrating odor of the escaping gas acetaldehyde. This is

(b) Pour 2 ml of methyl alcohol in a test tube which is standing in a beaker of water. Heat a copper spiral wire (Fig. 28) to a red heat in the upper part of the laboratory flame. On withdrawing the copper observe the black deposit of copper oxide Immediately lower it into the test tube of methyl alcohol. Repeat if necessary until the pungent vapor of formaldehyde is evident. Save the oxidized alcohol for the Hebrer recognitions.



Fig 28—Copper Spiral for Oxidation of Methyl Alcohol

What is the oxidizing agent in the preceding action?

How are aldehydes formed from alcohols?

(c) Reducing Agent. Aldehydes are readily oxidized

#### Instruction:

When heating material in a test tube, always hold the test tube obliquely in the flame, point the mouth away from anybody and, if a liquid, slightly agitate it by a sidewise shaking of the test tube

Benedict's Cuprous Oxide Test: Add a few drops of an aldehyde solution as formalin (40 per cent formaldehyde) (supply table) to 1 ml. of Benedict's solution, contained in a test tube Make the solution more alkaline with a few drops of sodium hydroxide solution, and with constant agitation of the liquid boil gently for a

minute and then cool. A yellow to red insoluble Cu<sub>2</sub>O is evidence of reduction.

2 Cu(OH)
$$_2$$
 + H · CHO  $\rightarrow$  Cu $_2$ O  $\downarrow$  + H · COOH + 2 H $_2$ O Cupric hydroxide Cuprous

 Tollen's Silver Mirror Test. Clean a test tube by boiling with dilute sodium hydroxide solution. Add a few drops of an aldehyde as formaldehyde (supply table) to 1 ml. of Tollen's ammoniacal silver nitrate solution. Warm the tube very gently without agitating the liquid. Silver is deposited.

The results of 1 and 2 show that aldehydes are agents. In these reactions the metallic hydroxides furnish oxygen for the oxidation of the aldehyde (or ketone) to form organic acids.

$$R \cdot CHO + O \rightarrow R \cdot COOH$$

3. Hehner's Resorcin Test: Add one drop of a 1 per cent resorcin solution to the oxidized alcohol, obtained in (b). Add 5 ml. of water and mix well. Carefully pour this mixture down the side of a test tube containing about 3 ml of concentrated H<sub>2</sub>SO<sub>4</sub>. A pink to a red ring (not brown) will be formed where the liquids meet. This is a method used to detect formaldehyde and thereby wood alcohol in a liquid.

Check tests 1, 2, 3 with the Instructor,

(d) MIR TEST: This test will detect one part of H·CHO in. 250,000 parts of milk. Add one drop of formalm to half a test tube of water. Mix thoroughly, pour out the solution, half fill the tube with milk, and shake so the milk will mix with the formalm clinging to the inside of the test tube. Add about 10 ml. of dulute HCI (one to three) and one drop of FeCl<sub>3</sub> (5 per cent). After mixing thoroughly stand in a beaker and heat to boiling. Why might milk

be found to contain formaldehyde?

#### C. ORGANIC ACIDS

(a) To the undistilled liquid from the alcohol experiment add blue litmus paper.

$$\begin{array}{c} C_2H_5OH \stackrel{O}{\longrightarrow} CH_3 \cdot CHO + H_2O \\ \text{Alcohal} & \text{Acetaldehyde} \end{array}$$

What acid is formed?

acid. Organic acids formed from

alcohols are due to what kind of reaction?

#### D. ESTERS

(a) To a solution of 2 ml. of ethyl alcohol in a dry test tube add 1 cc. of glacial acetic acid and very carefully a few drops of concentrated sulfuric acid. Carefully warm (very gently). Add water, agitate the liquid and then notice the ethereal, fruitlike odor of ethyl acetate, an ester produced by the process esterification. Esters are extensively used as artificial flavors. Notice the similarity between this method of preparation and the method used to prepare a salt by neutralization. The alcohol acts like a base but is too weak to affect litmus. The similarity between neutralization and esterification is shown as follows:

$$\begin{aligned} \text{NaOH} + \text{HCI} &\rightarrow \text{NaCI} + \text{H}_2\text{O} \\ \text{C}_2\text{H}_5\text{OH} + \text{CH}_3\text{COOH} &\rightleftarrows \text{CH}_3\text{COOC}_2\text{H}_5 + \text{H}_2\text{O} \\ \text{Alcohol} & \text{Exter} \end{aligned}$$

- (b) Repeat (a), using the same quantities of amyl alcohol, glacial acetic acid and concentrated sulfuric acid in a dry test tube Warm gently. The odor is that of a finger nail polish remover, and resembles what fruit?
- (c) Repeat (a), using the same quantities of the prepared (stock) methyl alcohol (wood)—salicylic acid solution and sulfuric acid in a dry test tube. Warm gently. What substance often used in liniments has this odor?
- (d) Repeat (a), using the same proportions of ethyl alcohol, butyric acid, and sulfuric acid in a dry test tube. Warm gently. What tropical fruit has a similar odor?
- (e) Hydrolysis: Esters are mostly insoluble in water and all undergo slight hydrolysis, i. e., they react with water to form the

original acid and base. The hydrolysis of esters is just the opposite of esterification. The concentrated sulfuric acid used in the preparation of the ester is a dehydrating agent and absorbs the water as fast as formed and consequently prevents a reversible reaction. Put one-half a milliliter of amyl acetate (an ester) into a dry test tube and test with blue litmus paper. Add 10 ml of H<sub>2</sub>O. Shake the test tube thoroughly, remove the litmus paper, and compare the color with another piece of blue litmus paper. Result?

Write the formula of the alcohol and the acid formed in such a way as to show the characteristic group of each

What is the name of the alcohol formed?

#### E. ETHER

To about 2 ml. of ethyl alcohol m a dry test tube, add drop by drop 0.5 ml. (eight drops) of concentrated sulfure acid, shaking and smelling after the addition of each drop of acid. The odor is that of ordinary ethyl ether.

2 C<sub>2</sub>H<sub>5</sub>OH 
$$\rightarrow$$
 \_ + H<sub>2</sub>O Ethyl ether

In the above reaction, what kind of an agent is sulfuric acid?

What is the main use of ethyl ether?

# EXERCISE 29—CHAPTER XV CARBOHYDRATES

Section Date Name

MAYERIAIS Starch, cane sugar, mith sugar, grape sugar, todine solution, Benedict's solution, fermentation tubes, cooked starch paste (1 per cent), uncooled starch solution (1 per cent) Optional Phenylhydrause solution, saturated solution chloride solution, glucose solution, glacial acetic acid, microscope and states.

#### Instructor:

If D is to be performed start a day or so before the regular laboratory period.

#### A. DEXTRIN FROM STARCH

- (a) IODINE TEST FOR STARCH: Add a few grains of starch to 10 ml. of water. Heat to boiling, cool, and then add a drop of iodine solution. A blue color indicates the presence of starch. Reserve this test.
- (b) STARGH TO DEXTRIN: Heat 3 Gm. of starch (5 ml.) in an evaporating dish on a wire screen over a very small flame with constant stirring. The flame must not touch the evaporating dish, and care must be taken not to burn the starch.\* At the end of several minutes the starch will become light brown. Continue the heating a few minutes longer with constant stirring. Cool. Use your finger to wipe up any unchanged starch clinging around the inside of edge of the dish. Fill the evaporating dish two-thirds full of water, stir, and filter. (While filtering, proceed to B.) Add a drop of iodine solution to 10 ml. of the filtrate A violet to a reddishbrown color (not blue) indicates the presence of destrin. To determine if the preparation of destrin is successful, dissolved a pinch of dextrin from the supply shelf in a test tube half full of water, and make the test with iodine. Compare these solutions with the one saved in (a), and check results with the Instructor.

Evaporate the remaining filtrate to about

<sup>\*</sup> If using the test tube holder to steady the evaporating dish while stirring, grasp the dish so as to enclose its lip

5 ml. and then with extreme caution nearly to dryness. Cool and taste a small portion of it. Why are toast and the crust of bread sweet?

Examine the dextrin between

moistened fingers. Result? What could it be used for?

#### B. REDUCING PROPERTIES

To 5 ml. of water in a test tube add a few milliliters of grape sugar solution. Now add to this sugar solution just enough of Benedict's solution to make it a light blue color. Heat to the boiling point. The formation of yellow cuprous hydroxide or red cuprous oxide indicates that glucose is a reducing sugar. Test in a similar way dilute solutions of lactose, sucrose, and starch (cooked or uncooked).

Are monosaccharides (dextrose) reducing agents?

The one

disaccharide which is not a reducing agent is

Are poly-

saccharides (starch) reducing agents? The reducing power of carbohydrates is due to the characteristic group, called the

#### C. HYDROLYZING PROPERTIES

(a) STARCH TO GLUCOSE: Boil 100 ml. of water in a beaker. Mix thoroughly by agitation in a test tube about one-half a gram of starch and 5 ml of cold water. Add this mixture to the boiling water and stir. Add about 0.5 ml. of concentrated hydrochloric acid and boil gently for about five minutes. The solution should now be colorless. Drop a piece of litmus paper in the solution and add sodium hydroxide solution, a few drops at a time, until the solution upon stirring reacts neutral or slightly alkaline. Add sufficient Benedict's solution to give a blue color, and boil to make

the test for glucose. Allow the solution to cool. Result?

Check with the Instructor

Complete the equation for the hydrolysis of starch (polysaccharides).

Hydrolysis of starch is produced in the mouth by

and

in the intestines by

(b) SUCROSE INTO GLUCOSE AND FRUCTOSE. To 5 ml. of dilute cane sugar solution add a drop of hydrochloric acid and boil gently for two minutes Make it alkaline to litmus paper with sodium hydroxide\* solution and test by Benedict's method Result?

Check result with the Instructor

Complete the equation for the hydrolysis of cane sugar (disaccharde).

$$C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 +$$
Glucose Fructose

The fact that a starch solution is cloudy (colloidal) and a sugar solution is clear shows what about the relative sizes of the starch and sugar molecules?

What kind of an agent is hydrochloric acid?

Hydrolysis of sucrose is produced in the intestines by

In cooking fruits containing acid why should the sugar not be added
until after the fruit is cooked?

Hydrolysis involves a reaction between a compound and

<sup>\*</sup>In the presence of a too strong solution of NaOH, a brown caramel like condensa toon product develops 'The action of an alkalı on a carbohydrate bearing a free arbonyl group to produce a brown product is noticed when too much sods is used as a leavening agent in baking.

#### D. FERMENTATIVE PROPERTIES

(Demonstration by designated students)

Fill five fermentation tubes (Fig. 29) with dilute solutions of starch, glucose, sucrose, lactose, and maltose, respectively. Introduce a few drops of yeast solution into each

What carbohydrates do not ferment?

Under certain pathological conditions the urine may contain milk sugar How could you determine whether the patient had diabetes or not, since milk sugar as well as dextrose responds to Benedict's test?

tube and place in a warm place until the next class

Fig 29

How do you account for the action of yeast on sucrose?

#### F. OXIDATION

Will a carbohydrate burn? In Exercise 26 a sugar was oxidized by copper oxide. What are the two compounds formed by oxidizing a carbohydrate? What else is formed that cannot be shown in the equation for the oxidation of a sugar?

### Summarv:

List four main chemical properties of carbobydrates

The test for a monosaccharide and all disaccharides, excepting sucrose, is made by .

#### F. DIGESTION OF STARCH PASTE

(Optional if Experiment on Digestion of Foods is to be performed)

(a) SALIVARY AMYLASE ACTION: To 5 ml. of dilute cooked starch paste (1 per cent) in a test tube add five drops of saliva and stir thoroughly. Hold the bottom of the test tube in your hand so as to keep the liquid near body temperature. At half-minute intervals or less remove one drop to an evaporating dish (or depressions in a white porcelain test tablet), and test for starch with a drop of dilute iodine solution. When no color is produced with iodine, test the remaining mixture for sugar (maltose) by boiling with Benedict's solution. and cooling. What range of colors did you obtain?

What intermediate product is produced in the digestion of starch to sugar by salivary amylase (ptvalin)?

(b) Using 5 ml. of raw (uncooked) starch paste (1 per cent) add five drops of saliva, and mix thoroughly. Make the iodine test at one-minute intervals over ten minutes. Then filter and test the

filtrate by Benedict's test. Result?

What is your conclusion?

#### G. FORMATION OF OSAZONE (OPTIONAL)

The monosaccharides and disaccharides, sucrose excepted, react with phenythydrazine to form osazones. Since different osazones have slightly different crystalline forms with different melting points the formation of osazones identifies the sugar from which it was formed.

To a test tube containing a mixture of five drops of phenylhydrazine, ten drops of glacial acetic acid, and 15 drops of saturated sodium chloride solution, add 3 ml. of glucose solution and boil for about three minutes. Place the test tube in a beaker of boiling water, and allow to cool. Remove some of the crystals, place on a glass slide, examine under a microscope, and sketch one or more crystals.

### EXERCISE 30-CHAPTER XVI FAT-SOAP

Section Date Name

MATERIALS Cottonseed oil, alcohol, sodium hydroxide (50 per cent), sodium chloride solution, sodium carbonate, potassium hydrogen sulfate, chloroform, ether, carbon tetrachloride, albumin solution, soap solution (1 10), 0.5 per cent sodium carbonate solution, rancid oil (one drop oleic acid to 2 cc of cottonseed oil), fresh olive oil, milk, blue litmus solution, pancreatic juice (0 I Gm pancreatin in 500 ml of 0.5 per cent Na2CO2), butter, glycerol, 2 per cent iodinechloroform solution

#### A. FAT

(a) DIGESTION OF FAT: Add sufficient blue litmus solution to 10 ml. of fresh milk to impart a noticeable blue color. Divide equally into two test tubes, and to the one add 1 ml. of artificial pancreatic juice. If both tubes are not the same color, add enough 0.5 per cent Na2CO3 solution to the one needing more alkali. Allow both tubes to stand in a beaker of warm water, approximately 37° C., until near the end of the laboratory period or longer. If an incubator is available, place the tubes in it instead of in the beaker of water. Hold the tubes together and compare their color by looking down into both tubes. The color of the litmus solution which con-

tains pancreatic juice is

, which indicates that an

is formed. In case the change in color is not very marked, warm slightly and smell both tubes. What is the odor of the milk containing the pancreatic juice? What

enzyme found in the pancreatic juice digests fat?

N. B. If the experiment on the Digestion of Foods (pp. 735 to 738) is to be performed, the following paragraph may be omitted.

Put a very small piece of butter into a test tube, add 5 ml. of

water and warm until the butter barely melts Add 5 ml. of pancreatic juice and shake thoroughly. Place the tube in the beaker of warm water and at the end of the laboratory period note the

change in odor. What acid has been formed? Note the change in appearance of the butter.

Write an equation to show the reaction produced by the lipase enzyme.

$$C_3H_5(OOCC_3H_7)_3$$
 + ...  $HOH$  -> +  $C_{ijceryl}$   $butyrate$   $C_{ijceryl}$   $butyrate$   $C_{ijceryl}$   $butyrate$   $C_{ijceryl}$ 

- (b) SPOT TEST FOR FAT: Place a drop of cottonseed oil upon a piece of paper. How does the spot compare with that produced by a drop of water?
- (c) SOLUBILITY OF FATS. Using a dry test tube, test the solubility of one drop of cottonseed oil in 5 ml. each of ether, carbon tetrachloride, chloroform [save for (e)], alcohol and boiling alcohol. Results?
- (d) EMULSION OF FATS. To a drop of cottonseed oil in a test tube add 10 ml of water and shake vigorously. Result?

Allow to stand a minute. Is a permanent emulsion formed? Now add a few drops of soap solution and shake again. Results?

Repeat the experiment using dilute albumin solution instead of soap solution. Is an emulsion always made permanent by the addition of a colloid?

Test the emulsification of a drop of fresh oil and a drop of rancid oil in separate test tubes, each containing 10 ml of water and five drops of 0.5 per cent solution of sodium carbonate. Result?

(e) UNSATURATED FAT TEST: Fats may be identified by estimating the quantity of iodine absorbed by the unsaturated esters present, the percentage absorbed being called the "iodine number."

In a test tube containing about 10 ml of chloroform and about 1 ml of dissolved vegetable oil (saved from (a)), add drop by drop a solution of iodime in chloroform (2 per cent) to give a faint violet color. Shake the tube thoroughly and allow to stand for ten

minutes or more. Again shake the tube. Result? . . . . . . . . . . Structurally how does an unsaturated fat, such as olein, differ from

a saturated fat?

Is the reaction of an unsaturated fat with iodine an example of addition or substitution?

#### B. SOAP

(a) SAPONIFICATION OF FATS: Place in an evaporating dish 8 ml. of cottonseed oil, and an equal volume of ethyl alcohol (solvent) and 15 drops of the sodium hydroxide solution (50 per cent) from the supply table. Stir, and with a small flame warm very gently until the alcohol evaporates. (If the alcohol catches fire no harm is done, but extinguish by placing a sheet of paper on top of the dish.) The pasty mass, mainly sodium oleate mixed with glycerin, is soap. The process of treating a fat with an alkali to form a soap

is called

 $C_3H_5(OOCC_{17}H_{33})_3 + 3 NaOH \rightarrow C_3H_5(OH)_3 + Glycerin Sodium Intoleate (glycerol) oleate$ 

(The alcohol is used as solvent to save time and is not used commercially.)

(b) FATTY ACIDS. To the soap in the evaporating dish add water and warm to dissolve the soap Save one-half a test tube of this solution for the next experiment, and to the remaining soap solution add a strong mineral acid as hydrochloric acid until a precipitate (liquid here) forms upon stirring vigorously.

 $C_{17}H_{33}COONa + HCI \rightarrow NaCI +$  Oleic acid

Heat the mixture to boiling and filter through a wet filter. The residue on the filter paper is oleic acid and the above reaction represents a general method of obtaining an organic acid from its salt.

Is it soluble in water? Transfer some of the liquid or the solid residue from the filter paper to a test tube, add 10 ml. of water and a few milliliters of sodium hydroxide solution. Heat until solution takes place.

C<sub>17</sub>H<sub>33</sub>COOH + NαOH → H<sub>2</sub>O + Sodium elec (Social What characteristic property of an acid is shown in the above equation?

A soap is a metallic

salt of a

(c) "SALTING OUT": To the one-half test tube of soap solution obtained in (b) add sodium chloride solution Result?

This is called "salting out," and is an example of precipitating a colloid. What important commercial product is present in the brine below the soap?

(d) GLYCERIN (GLYCEROL): To a drop of glycerin in the bottom of a dry test tube add a few crystals of potassium hydrogen sulfate. Heat cauthously, and note the irritating odor of acrolem, which is formed by dehydrating glycerin according to the following equation:

> C<sub>3</sub>H<sub>5</sub>(OH)<sub>3</sub>  $\xrightarrow{\text{KHSO}_4}$  C<sub>2</sub>H<sub>3</sub>CHO  $\div$  2 H<sub>2</sub>O Actrolein (propendi)

Repeat the test for glycerin by using a few drops of any fat Why may this procedure be used as a test for any fat?

Since fats decompose when heated alone to a high temperature, would *intense* heat used in cooking fatty foods improve their flavor and digestibility?

## EXERCISE 31—CHAPTER XVII PROTEINS

Section Date Name

MATERIALS: Egg albumin solution (white of one egg thoroughly shaken with 300 ml of water). I per cent CuSO<sub>4</sub> solution, Millon's reagent (one part by weight of mercury dissolved in two parts by weight of concentrated nitric acid and diluting the resulting solution with two volumes of water), dilute solutions of phenol, gelatin, mercuric chloride, lead acetate, silver nitrate, copper sulfate, ferric chloride, tannic acid (fresh), pierra acid, dilute acetic acid, alcohol, ammonium sulfate crystals Cotton thread, silk thread, wool yarn

### A. SOLUBILITY

- (a) Obtain approximately 150 ml. of egg white solution from the supply table. Observe the flaky precipitate. What simple protein is not soluble in plain water, but is soluble in salt water?
- Start the filtering of the entire quantity of egg white solution, and use the clear egg albumin solution for the following protein reactions:
  - (b) What kind of a solution does albumin form with water?

Can albumin (colloidal) be separated from solu-

tion by filtering through filter paper? It can be separated unaltered though from a crystalloid in solution by a process called

(c) Place a few milhilters of albumn solution in a test tube and shake vigorously. What is characteristic of protein solutions upon shaking? Can colloidal food be absorbed di-

rectly by the intestinal wall? What changes the col-

loidal material into an easily absorbable form?

## B. COLOR REACTIONS

## Instruction:

Color reactions are due to a reaction between some one or more of the radicals of the complex protein molecule and the chemical reagent used in any test.

- (a) Xanthoproteic Reaction: To about 3 ml of egg albumin solution in a test tube add a few drops of concentrated nitric acid A white precipitate forms, which upon heating turns yellow and finally dissolves, imparting to the solution a yellow color. Cool and finally dissolves, imparting to the solution a yellow color. Cool and cautously neutralize by adding the alkali, ammonium hydroxide, in excess The yellow color deepens to an orange. Nitric acid on the skin produces a yellow color, which becomes orange when treated with ammonia water or soan
- (b) BIURET TEST: To 3 ml of egg albumin solution in a test tube add 1 ml. of sodium hydroxide solution and then slowly a few drops of a 1 per cent copper sulfate solution At the end of a minute a nink to violet color is produced.
- (c) MILLON'S REACTION: To 3 ml. of egg albumin solution in a test tube add a few drops of Millon's reagent A white precipitate

forms which upon heating slowly turns and then This color is due to the hydroxyphenyl group ( $-\text{CoH}_0\text{H}$ ), which is present in many proteins. Repeat Millon's test with a solution of phenol ( $\text{CoH}_5\text{OH}$ ), and then of gelatin. Result and conclusions?

### C. COAGULATION OR HEAT TEST

- (a) Pour a test tube full of dilute egg albumin solution into an evaporating dish, and heat to boiling. Complete coagulation may be obtained by acidifying with two drops of acetic acid. Remove some of the coagulated albumin and make the burset test. Allow to stand for a minute. What is the color of the coagulation?
- (b) Fill a test tube almost full of albumin solution With a small flame carefully heat the middle portion of the liquid in the test tube to boiling by inclining the tube over the flame. Compare the

lower part to the heated part. Result?

(c) Pour out half of the solution, heat the remaining portion to boiling, and filter. Make the biuret test on the filtrate. Result?

What is the effect of heat on protein in solution?

When heating milk or making soups from meat, what is the coagulated substance collected on the surface of the liquids?

(d) Place 5 ml. of clear albumin solution into three separate test tubes To the first add one drop of dilute acetic acid, and to the second four drops of dilute sodium hydroxide. Place all three tubes in a beaker of water. Heat the water and watch to see what hap-

pens Is coagulation facilitated by dilute acid or alkali?
Add 2 ml. of concentrated hydrochloric acid to the acid tube and
boil. Add 2 ml. of sodium hydroxide (10 per cent) to the alkali
tube and boil. Results?

## D. PRECIPITATION REACTIONS

Various salts, mineral acids, alkaloidal reagents, and alcohol are able to precipitate proteins.

(a) PRECIPITATION BY SALTS OF HEAVY METALS Prepare five test tubes, each containing about 3 ml. of dilute egg albumin solution and a drop of sodium hydroxide solution. To the first test tube add mercuric chloride solution, drop by drop, until an excess of the reagent has been added, noting any changes which may occur. Repeat, using lead acetate, silver nitrate, copper sulfate, and ferric chloride solutions.

Salts of Heavy Metals	Results	
HgCl <sub>2</sub>		
Pb(C <sub>2</sub> H <sub>N</sub> O <sub>2</sub> ) <sub>2</sub>		
AgNO <sub>3</sub>		
CuSO <sub>4</sub>		
FeCl,		

Egg albumin is used as an antidote for mercury or lead poisoning Why?

(b) PRECIPITATION BY ALKALOIDAL REAGENTS Prepare two test tubes, each containing 3 ml of dilute egg albumin solution and a drop of dilute acetic acid. To one add a few drops of tamic acid solution and to the other add a few drops of picric acid solution.

Results?

- (c) PRECIPITATION BY NITRIC ACID (HELLER'S RING TEST) Place 5 ml of concentrated HNO<sub>3</sub> in a test tube incline the tube, and by means of a pipetic (glass tube) allow the dilute albumi solution to flow slowly down the side A white zone of precipitated albumin forms at the point of juncture This is a very delicate test and is used extensively in urinalysis.
- (d) PRECIPITATION BY ALCOHOL Add a few drops of egg albumin solution to 5 ml of alcohol contained in a test tube The fixing of tissues for histological examination by means of alcohol is an illus tration of the application of this transformation produced by alcohol. The proteins are precupitated unaltered, and probably are dehydrated by the alcohol
- (e) 'SALTING OUT To a test tube one third full of egg albumin solution add ammonium sulfate crystals slowly and with constant stirring until a saturated solution is formed. The proteins are precipitated unaltered. Filter off the precipitate and test the filtrate for protein by any one of the previously tried tests. Is albumin completely precipitated in a saturated solution of ammonium sul.

fate? Check result with the Instructor

In the previous precipitations the protein had combined with the reagent, D(a), (b), (c), or it had been coagulated by heat, C(a), or alcohol, B(d), so that it was permanently changed In list week's experiment (Fats) what colloidal substance was 'salted out'

of solution?

# Summary:

Protein in solution may be precipitated by

## E. TEXTILE FIBERS

(Optional)

Obtain from the supply table, nine threads, three each of wool, salk, and cotton for the following experiments

(a) Effect of Heat: Light separately the end of a thread of wool, silk, human hair, and cotton; then withdraw from the flame
Which continues to burn?

Which gives the least odor?

How may you distinguish between animal fibers

(wool, silk) and vegetable fibers (cotton, linen)?

(6) EFFECT OF A STRONG BASE Place a thread of wool, silk, and cotton in separate test tubes, each about one-eighth full of sodium hydroxide solution (10 per cent) and boil gently for a minute Result?

Result?

What kind of fiber is dissolved? composition of this kind of fiber? What is the

(c) Effect of a Concentrated Strong Acid. Repeat (b), using concentrated hydrochloric acid instead of the sodium hydroxide solution? Result?

- (d) Effect of Salts from the Body How do the salts of the body in perspiration affect the protein fibers as in silk and wool?
- (e) SUMMARIZE THE PROPERTIES OF ANIMAL AND VEGETABLE

Effect of	Animal Fiber (wool and silk)	Vegetable Fiber (cotton)
Heat (flame)		
Bases (strong) (NaOH)		
Acid (cone ) (HCl)		

# EXERCISE 32-CHAPTER XVIII THE CHEMISTRY OF DIGESTION

Section Date Name

MATERIALS Starch paste (one gram of starch ground thoroughly in a mortar with enough water to make a thin poste, and then poured slowly into 100 ml. of boiling water), dilute votine solution, Benedict's solution, raw starch solution (in per cent), artificial pancreatic pluce (one gram pancreatin in 100 ml of 0 5 per cent Na<sub>2</sub>CO<sub>3</sub>, hard-boiled egg white, neutral pepsin (I per cent), artificial gastre pluce (I Gm pepsin in 100 ml of 0 4 per cent H2Cl), 0 5 per cent Na<sub>2</sub>CO<sub>3</sub> solution, cream porcelain test tablets

### A. STARCH

(a) SALIVARY AMYLASE: Have ready about 3 ml. of dilute iodine solution for your different starch tests To 5 ml. of cooked starch paste (1 per cent) in a test tube add five drops of saliva and stir thoroughly. At two-minute intervals or less, remove one drop to an evaporating dish (or depression in a white porcelain test tablet), and test for starch with a drop of dilute iodine solution. When no color is produced with iodine, test the remaining liquid for sugar (maltose) by boiling with Benedict's solution, and then cooling.

What range of colors did you obtain in the iodine tests?

What intermediate product is produced in the digestion of starch to sugar by salivary amylase (ptyalin)?

Using 5 ml. of raw (uncooked) starch paste add five drops of saliva, and mix thoroughly. Make the jodine test several times during the next 10 or 15 minutes. Filter, and test the filtrate for sugar by boiling with Benedict's solution.

What difference do you find in the digestive action and time action of saliva on cooked and uncooked starch?

### B. FATS

(a) PANCREATIC LIPASE (STEAPSIN): To 1 ml of cream add 5 ml. of milk or water, and an equal volume of artificial pancreatic juice.

Shake the mixture thoroughly Keep at 37° C for an hour or more, and note any change in odor. Warming the tube will make the odor more noticeable. The smell indicates that the substance formed is

Fats must be in an emulsified condition before they can be hy drolyzed In the hydrolysis of fats what products are formed?

### **C PROTEINS**

- (a) GASTRIC PROTEASE (PEPSIN) AND PANCREATIC PROTEASE (TRYPSIN) Place a small piece of the white of a hard boiled egg in three separate test tubes
  - 1 To the first add 10 ml of artificial gastric juice
  - 2 To the second add 10 ml of artificial pancreatic juice
  - 3 To the third add 10 ml of water as a control

Label the tubes and keep at 37° C for several hours Examine at the end of several hours for indications of digestion

What digests proteins?

Filter the liquids in which digestion appeared to take place and make the hurst test on each filtrate. Result?

Pancreatic suice contains three ferments

- 1 Trypsin, which changes albumin or proteins to peptones
- 2 Amylopsin, which changes starch to glucose
- 3 Steapsin, which emulsifies and hydrolizes fats or oils

Why in all digestion experiments should the temperature of the test tube not vary widely from 37° C?

# EXERCISE 33-CHAPTER XVIII MEDIUM FOR ENZYME ACTION

Section Date Name

MATERIAIS Starch, paste (1 per cent), 0 4 per cent HCl, 0 5 per cent Na<sub>2</sub>CO<sub>3</sub>, neutral pepsin solution (1 per cent), neutral pancreatin (1 per cent), hard boiled egg white, 1 per cent CuSO<sub>4</sub>, dilute iodine solution

- (a) Salivary Amylase Place 2 ml of starch paste (1 per cent) and five drops of saliva in each of three test tubes.
  - 1. To test tube 1 add 2 ml. HCl (0.4 per cent).
  - 2. To test tube 2 add 2 ml Na<sub>2</sub>CO<sub>3</sub> (0 5 per cent).
    - 3 To test tube 3 add 2 ml. H<sub>2</sub>O (control tube).
- Label, mix by agitating the contents of each tube, and keep at 37° C. in a beaker of water. Test a drop of each tube frequently with a drop of iodine until certain of the best medium for salivary

digestion Result?

Nors: The nine test tubes used in this and the next two tests may be conveniently placed in a beaker for incubation. If pressed for time, or for space in the incubator, a group of students, with the consent of the instructor, may work together

- (b) PEPSIN: Place uniform sized pieces of the white of hardboiled egg and 2 ml of neutral pepsin solution (1 per cent) in each of the three test tubes.
  - 1. To test tube 1 add 2 ml. HCl (0 4 per cent).
  - 2 To test tube 2 add 2 ml. Na<sub>2</sub>CO<sub>3</sub> (0 5 per cent).
  - 3 To test tube 3 add 2 ml. H2O (control tube).

Keep at 37° C. for several hours. Compare the appearance of the tubes, and then make the biuret test in each tube. What is the best medium for pensin digestion of protein?

- (c) PANCREATIC PROTECLYSIS. Place a uniform sized particle of the white of a hard-boiled egg in 2 ml of neutral pancreatin (1 per cent) in each of three test tubes
  - 4 To test tube 4 add 2 ml HCl (0 4 per cent).
  - 5 To test tube 5 add 2 ml Na<sub>2</sub>CO<sub>3</sub> (0.5 per cent).
  - 6. To test tube 6 add 2 ml. H2O (control tube).

Label and keep at 37° C and examine at the end of one hour Compare and make the biuret test in each tube Results and con clusions?

- (d) PANCREATIC AMYLOLYSIS Place 2 ml of starch paste (1 per cent) and 2 ml of neutral pancreatin (1 per cent) in each of three test tubes
  - 7 To test tube 7 add 2 ml HCl (0 4 per cent)
  - 8 To test tube 8 add 2 ml Na<sub>2</sub>CO<sub>3</sub> (0 5 per cent)
  - 9 To test tube 9 add 2 ml H<sub>2</sub>O (control tube)

Label and keep at 37° C for one hour Follow the digestion with the iodine test What is the most favorable condition for the action of amylopsin?

What are your conclusions regarding the optimum reaction of the following enzymes

Ptyalin

Pepsin

Trypsin (pancreatic protease)

Amylopsin (pancreatic amylase)

# EXERCISE 34—CHAPTER XVIII TESTS FOR NUTRIENTS IN FOODS

Section Date Name

MATERIALS Iodine solution, Benedict's solution, 1 per cent copper sulfate solution, grape sugar solution, ether, starch, flour, potatoes, butter, green and ruce bananas, carrots, onions, cheese, peanut butter, cooked egg white, cooked egg yolk, other foods as time permits

- (a) STARCH: Boil a few grains (not grains) of starch in a test tube half full of water. Cool by holding it under running cold water, and then add one drop of iodine solution. A deep blue color indicates starch. Test in a similar way the food samples. The egg should be hard boiled before testing.
- (b) GLUCOSE: Add a few drops of grape sugar solution to half a test tube of water, and then Benedict's solution sufficient to give a very light blue. Boil. A yellow to red precipitate indicates the presence of a simple sugar such as glucose or fructose. What disac-

charides show reducing properties?

Test the food samples for sugar by boiling small pieces of each in water colored blue with Benedict's solution.

- (c) FATS: Meats and butter furnish most of the fats which serve as food. To examine foods for oil or fat, shake carefully a small portion of the food with half a test tube of ether. Filter into an evaporating dish and allow the filtrate to evaporate without heating. The residue in the dish when placed on paper, warmed and held to the light will be translucent as an indication of a fat
- (d) PROTEINS Pour a few milluliters of the buret reagent, prepared by adding a drop of a 1 per cent CuSO<sub>4</sub> solution to a few milluliters of NaOH solution, upon a small portion of the food sample. Allow to stand for a few minutes A pink to violet indicates protein.
- (e) MINERAL MATTER: Burn a very small sample of food such as cheese on an evaporating dish until all of the black carbon is oxi-

dized. What is the residue?

Analyze the different foods on the supply table for starch, glucose, protein, and fat, and indicate by a positive sign (+) the nutrients found in each food.

## Analysis of Foods

Food	Starch	Glucose	Protesn	Fat
Banana, ripe		ļ		
Banana, green			 	
Butter				
Carrot				
Egg white (cooked)				
Egg yolk (cooked)				
Flour				
Onion				
Peanut Butter				
Potato				
Cheese				

# EXERCISE 35-CHAPTER XIX TESTS FOR SOME BLOOD CONSTITUENTS

Section Date Name

MATERIALS Blood lancet, 0.85 per cent NaCl solution, 10 per cent sodium ungstate solution, 2/3 N H<sub>2</sub>SO, (35 Gm conc. C. P. H<sub>2</sub>SO, dutated to a volume of one liter), Folin-Wu blood sugar reagent (dissolve in 100 ml of H<sub>2</sub>O 10 Gm anhydrous sodium carbonate, 18 Gm tartaric acid, 1125 Gm CuSO, 5 H<sub>2</sub>O, and dilute to 250 ml), AgNO<sub>3</sub> solution, H<sub>2</sub>O, solution, Fieshly prepared saturated solution of benzidine in glacial acetic acid, glass slides, cover glasses, microscope, 1 ml of fresh (oxalitet) blood for each student, each to fit test tibe

Blood It may be possible to obtain suitable oxalated or citrated blood and also blood plasma from a hospital Where only a few drops of blood are needed it is best provided by the student by pricking the tip of a finger with a sterile needle, et Usually beef blood can be obtained from a slaughter house (abattor) Place in a flask 0.2 gm of powdered polassium oxalate for each 100 ml of blood Immediately upon obtaining the blood from the animal pour it into the flash, sopper security, and genity surft the flash to dissolve the oxalate Also, any veterinarian should be able to obtain a pint or more of blood from the jugular vein of a cow without any nighty to the animal

(a) MICROSCOPIC APPEARANCE: Place one drop of your own blood on a glass slide, cover with a cover glass, and examine under the microscope. Dulute the drop of blood (or a fresh drop of blood) with a few drops of isotonic sodium chloride solution, and again examine under the microscope. Draw some of the observed cells.

(b) Blood Protein Precipitation. Place 1 ml. (15 drops) of fresh blood (or oxalated blood) in a test tube, dilute with 7 ml. of water, and mix Add 1 ml of 10 per cent sodium tungstate solution and 1 ml. of sulfuric acid that is labeled 2/3 N·H<sub>2</sub>SO<sub>4</sub>. Close the mouth of the tube with a cork and shake the tube vigorously. At the end of about five minutes a bright red to dark brown coagulum of the proteins forms. The sodium tungstate-sulfuric acid mixture forms tungstic acid, which, like tannic and picric acid, acts as an alkaloidal reagent.

What are alkaloidal reagents used for?

Filter through a wet filter paper into a test tube and save the protein-free filtrate for the next two experiments. If the filtrate is not clear, refilter through the same filter paper.

- (c) BLOOD SUGAR TEST. To 2 ml. of the tungstic acid filtrate saved from (b) add an equal volume of the Folin-Wu blood sugar reagent (a modified Fehling's solution). Stand the tube for six minutes in a beaker of boiling water. Cool in running water (without shaking) for two or three minutes. A greenish-yellow to a yellowish-red color indicates that blood sugar has reduced the alkaline copper solution to cuprous oxide.
- (d) BLOOD CHLORIDE TEST. To 2 ml. more of the tungstic acid filtrate from the Blood Protein Precipitation Test, add a few drops of nitric acid (filter if cloudy), and then some silver nitrate solu-

tion. Result?

What ion is silver nitrate a test for?

- (e) TESTING FOR CATALYTIC ACTION OF BLOOD. If not familiar with the foaming produced by hydrogen peroxide on a bleeding cut, place a few drops of blood on a glass plate and add twice its volume
- of hydrogen peroxide. What causes the foaming?
- (f) Bloop Tests: Of the several tests for the presence of blood, the benzidine test is the most delicate (1:5,000,000) and valuable for clinical work, while the hemm test is the most conclusive for medicolegal work
- 1. Benzidine Test. Dilute one drop of blood with a test tube of water. To 2 ml. of a freshly prepared saturated solution of benzidine

in glacial acetic acid, add an equal volume of hydrogen peroxide solution. Mix well, and add a few drops of the dilute blood solution.

Result? The intensity of the color depends upon the amount of blood present.

If a blood stain were on cloth would you use hot or cold water for removing the blood?

Why?

2 Hemin Test: Place a very small drop of blood on a glass slide, dulute with a drop of water, add a minute crystal of sodium chloride, and carefully evaporate to dryness over a small fiame. Adjust a cover glass, run underneath the glass a drop of glacial acetic acid, and warm gently until gas bubbles are noted. Add one more drop of acetic acid, allow to cool, and examine under the microscope for crystals of hemin (Teichmann's). Sketch some observed crystals

# EXERCISE 36—CHAPTER XIX CLOTTING AND PROPERTIES OF BLOOD

Section Date Name

MATERIALS Test tube containing 5 ml of 24 hour old blood specimen from which the serim has separated test tube containing 5 ml of 24 hour old blood sample mixed with 0.01 Cm of powdered potassium oxidate (0.2 per cent solution of the exadale in blood). In all of firmated blood for each student other or chloro form glass sl des cover glasses microscope concentrated ammonium sulfide solution marble chips (CaCC), orthe 16 fit est time 2.0% potassium oxidate not to marble chips (CaCC), orthe 16 fit est time 2.0% potassium oxidate not concentrate two applicators or tooth pichs skin disinfectant ants A serum and ants.

#### A CLOTTING OF BLOOD

(Demonstration and Reference to Text)

(a) Bloop Clot and Serum Observe a test tube that contains 5 ml of a 24 hour blood specimen

What name is given to the light yellow liquid that has separated from the blood clot?

What is the name of the enzyme that causes blood to clot?

Why is the clotting of blood important?

Of what is the blood clot composed?

(b) BLOOD ANTI COAGULANTS Observe a test tube that contains 0 01 Gm of powdered potassium oxalate dissolved in 5 ml of a 24 hour old blood specimen What did the oxalate do to the

calcium ions of the blood?

(Demonstration) Carefully add a few drops of a 1 per cent solution of calcium chloride to the oxalated blood and allow it to stand There should be an excess of calcium ions present but any

great excess will hinder the clotting Does a clot form?

What metallic ion is necessary for the clotting of blood?

The normal clotting of the blood is hastened by the action of thromboplastin of the tissues in the presence of calcium Why does the blood not normally coagulate in the veins?

(c) PREPARATION OF DEFIBERNATED BLOOD (Demonstration or previously prepared): Defibrinated or "whipped" blood is obtained by rapidly stirring freshly drawn blood until the fibrin separates as a stringy mass upon the stirring instrument. One ml. of defibrinated blood is needed for each student. How does fibrin differ in composi-

tion from the blood clot?

## B. PROPERTIES OF HEMOGLOBIN

- (a) Hemolysis or Laking of Blood: When the hemoglobin of the red corpuscles escapes into the surrounding fluid, "hemolysis" or the "laking" of blood has taken place To show that hemolytic action can be produced arrange three test tubes as follows:
  - No. 1. 9 ml. of distilled water + 9 drops of defibrinated blood.
- No. 2  $\,^{\circ}$  2 ml of 0.85 per cent NaCl solution + 2 drops of defibrinated blood.
- No 3, 2 ml of 0.85 per cent NaCl solution + mixture of two drops of defibrinated blood and two drops of ether or chloroform.

Unchanged corpuscles give a cloudy (colloidal) appearance, while transparent solutions show that hemolysis has taken place. Place a drop from No 1 tube on a slide, adjust a cover glass, and examine under a microscope. Examine a drop from tubes No. 2 and No. 3 in the same way Compare the observed objects with the normal erythrocytes and leukocytes (see pp. 444 and 446). In what tube do you observe unchanged corpuscles?

What causes hemolysis?

How may anesthetics affect the erythrocytes of some patients?

Sometimes the bile enters the blood stream and indicates a condition known as jaundice. What effect does the bile have upon the red cells?

What prevents hemolysis from taking place in the plasma?

(b) OXTHEMOGLOBIN AND HEMOGLOBIN (SO CALLED REDUCED HEMOGLOBIN) Divide equally, in three test tubes the 9 ml of hemoglobin solution saved in tube No 1 Cover the mouth of one tube with a cork and shake it vigorously with the air in the tube The bright red color is due to oxyhemoglobin Save this tube for comparison

Set up the carbon dioxide generator (Fig. 30), and pass  $CO_2$  for

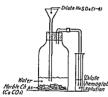


Fig 30-CO, Generator

a few minutes through 3 ml of dilute hemoglobin solution con tained in the second test tube. Cover with a cork the mouth of this tube containing the dark solution, and shake it thoroughly with the air contained in it. What color change takes

place?

In a few minutes the red color of the blood changes to a dark color owing to the CO<sub>2</sub> driving out the oxygen and to some extent uniting with the hemoglobin

Blood that is dark in color is poor in

but rich in

In what place in the body is reduced hemoglobin formed?

(Oxyhemoglobin may also be reduced by adding one drop of con centrated ammonium sulfide solution and gently warming the mixture)

(c) CARBON MONOXIDE HEMOGLOBIN Pass natural gas (posson ous, contains some CO) slowly through the third portion of dilute blood (hemoglobin) for at least ten munites Carbon monoxide he moglobin is a trifle brighter tint (carmine) than oxyhemoglobin in strong solution If there is no noticeable difference in color, dilute this tube, and also the oxyhemoglobin tube saved from the previous experiment, with equal amounts of water. In very dilute solution the carbon monoxide hemoglobin assumes a bluish-red color, while the oxyhemoglobin appears yellowish-red. This test is frequently used in detecting carbon monoxide poisoning.

(d) STABILITY OF CARBON MONOXIDE HEMOGLOBIN (Demonstration): There are other agents besides CO that will reduce oxyhemoglobin, such as ammonium sulfide (NH $_{\rm d}$ )s. Add one drop of concentrated (NH $_{\rm d}$ )s to 5 ml. of dilute blood solution. Warm very gently, and note the change in color from red to dark, due to the formation of reduced hemoglobin.

Prepare 5 ml of carbon monoxide hemoglobin as in (c), add a drop of (NH<sub>4</sub>)s<sub>5</sub>, and note there is no change in color as in above. What does this show about the union of carbon monoxide with hemoglobin?

Explain how carbon monoxide poisoning gives rise to suffocation'

It is for a similar reason that the gases, hydrogen sulfide and nitric oxide, are poisonous

(e) KALARMA'S TEST FOR CARBON MONOXIDE HEMOGLOBIN: This test is not only easy to perform, but also will detect as little as 10 per cent of saturation with carbon monoxide.

Place about 10 ml. of water in each of two test tubes. To one test tube add five drops of the blood suspected of containing carbon monoxide, and to the other test tube add five drops of normal blood as a control solution. Add five drops of freshly prepared concentrated solution of ammonium sulfide to each test tube, mix gently, and then make faintly acid with acetic acid.

Blood containing carbon monoxide hemoglobin gives a rose to red color, the depth of color depending upon the concentration. The control solution containing the normal blood develops a dirty greenish brown color.

#### C. REOOD GROUPING\*

Label one slide anti A and another anti B.

Put a tiny droplet of potassium oxalate solution onto each slide.

After sterilizing both the finger tip (not index finger) and the needle or lancet, nuncture the skin with a firm motion so as to cause blood to flow freely. (Suggestion: One student may puncture another student's finger). Add several drops of blood to the oxalate on each slide, mixing thoroughly with separate applicators or toothpicks, leaving ends of applicators in place on their respective slides.

Immediately add two drops anti A serum to the exalated blood on the slide labeled anti A and two drops anti B serum to the slide labeled anti B. then mix well. Rock the slides gently for about one minute, then observe for agglutination.

Did anti A serum cause agglutination of your red blood cells?

Did anti B serum cause agglutination of your red blood cells?

I therefore conclude that my blood is (See page 453, 455 for interpretation.) Group

Check results with your Instructor.

<sup>\*</sup>Some workers use a concentrated solution of blood in physiologic saline solution for blood grouning.

# EXERCISE 37-CHAPTER XX NORMAL URINE

Section Date Name

MATERIALS Six ounces of 24-hour sample of urine, Vogel scale, urinometer, centrifuge and tubes, microscope, slides and cover glasses, silver nitrate solution, barium chloride solution, acette acid Magnesia mixture (dissolves 17 5 Gm of magnesium sulfate and 35 Gm of ammonium chloride in 140 ml of distilled water, add 70 Gm of conc. NH4OH. and keep in a elass-stoopered bottle).

Beginning in the morning collect all your urine passed for the next 24 hours.

After measuring, save six ounces for analysis

#### A. PHYSICAL CHARACTERISTICS

- (a) VOLUME: Using a liter graduate measure, record the volume of urine excreted ml High urine excretion is called while low excretion is called
- (b) COLOR: Compare one-half a test tube of filtered urine with a

  Vogel scale and record the color How does the volume
  excreted affect the color of normal urine?
  - (c) TRANSPARENCY. Record the appearance (clear, turbid, etc.)

Turbid urine may be due to bacterial decomposition of urea, or to phosphates and urates, which will precipitate in a cold or low-acid urine. Permanent turbid urines are pathological. Phosphates dissolve on acidifying the urine with acetic acid, while urates become soluble upon warming the urine. Do you have phosphates or urates, or both, in your sample?

- (d) REACTION: Record the action of litmus paper as neutral, faintly or distinctly acid, or alkaline
- (e) Specific Gravity: Fill the urmometer cylinder threequarters full with urine, remove any froth with a piece of filter

paper, introduce the urinometer slowly with a slight spin, allow it to come to rest free from the cylinder, and read the scale at the

lowest part of the meniscus. Record the reading Normal urine varies from 1.015 to 1.024 at 25° C,

INSTRUCTION: Rinse the urinometer with water, and return it and the cylinder to the instructor.

(f) Total Solids: Multiply the second and third figures of the decimal portion of the specific gravity by 2.6 to get the approximate amount of solids in 1000 ml. Calculate the total solids in your 24-hour collection.

Total solids usually vary from 40 to 60 Gm.

(g) MICROSCOPIC EXAMINATION OF SEDIMENT (OPTIONAL): Pour 15 ml of urine containing sediment into a centrifuge tube, and centrifuge at a moderate rate of speed for about three minutes. Drain off the liquid, transfer some of the sediment to a microscopic slide, add a drop of urine, cover with a cover glass, reduce the light to a minimum and examine under the low-power microscope.

Urinary sediments are classified as organized (formed elements) and unorganized (crystalline and amorphous) sediments, of which the organized are of the greatest clinical unportance. To this latter group belong the red corpuscles, leukocytes, mucous threads, epithelium, spermatozoa, cylindruds, casts and pus. Examination of urinary sediment is frequently made with the primary object of determining the presence or absence of casts.

It is important that you become familiar with a normal urine before attempting a microscopic examination of pathological urine.

## B. TESTS FOR INORGANIC SALTS (OPTIONAL)

Before carrying out chemical tests, filter the urine until clear, and if albumin is present remove it by adding a few drops of nitric acid, boiling, cooling, and filtering.

(a) CHLORIDES: Acidify 10 ml. of urine with nitric acid, and add a drop of silver nitrate solution. Result?

- (b) SULFATES: Acidify 10 ml of urine with acetic acid, and add a drop of barium chloride solution Result?
- (c) PHOSPHATES. Make 10 ml of urine alkaline with ammonium hydroxide, and warm. Result?

The earthy phosphates or phosphates of calcium and magnesium separate. Filter off the earthy phosphates and add a small amount of magnesia mixture to the filtrate Warm the solution. Result?

The alkaline phosphates or the phosphates of sodium and potassium separate. Which form of phosphates is present in the larger amount?

# EXERCISE 38-CHAPTER XX PATHOLOGICAL URINE

Section Date . Name

MATERIALS Robert's reagent (five parts of saturated magnesium sulfote and one part of concentrated natire acid), dutte acetic acid (3 per cent). Benedic's qualitative and quantitative solutions, test tubes (25 x 150 mm), 2 ml Mohr pipettes, sodium carbonate, sodium nitroprusside, 10 per cent ferric chloride, todine solution (1250ml alcohol), freshly prepared saturated colution of bearden in glacial acetic acid, Obermayer's solution (1 Gm. of FeCl<sub>3</sub> in 500 ml, HCl), hydrogen peroxide, chloroforth Collections of urine known to contain albumin, sugar, acetone bades, bile, and blood

Note: In order to give a quantitative significance to a qualitative test, it is suggested that you use the terms "faint trace (delacte), trace, small, moderate, large," or "very large amount". It is also suggested that you carry out at the same time tests for both normal and pathological urnes in order to see the contrasts between them, and thereby make your pathological tests more certain.

(a) Albumn: The presence of albumin in the urine more frequently is associated with inflammatory or degenerative changes in the kidneys and less frequently with inflammatory changes in the tract below the kidneys. Tests for albumin in urines involve precipitation reactions, either due to the formation of an insoluble compound or the insolubility of the albumin in the reagent employed. Clear urines must be used in chemical tests. Clarity by filtering through filter paper, or, if necessary, by shaking with powdered magnesium oxide and then filtering.

Coagulation Test: Almost fill a test tube with urine, and heat the upper portion to boiling. If the heated portion becomes cloudy the turbidity may be due to phosphates. The addition of two drops of dilute acetic acid and warming again will dissolve the phosphates, while a more flocculent precipitate will be produced if only albumin is present.

Heller's Test: Place a few ml. of concentrated nitric acid in a test tube, slant the tube, and very carefully allow an equal amount of urine to slowly run down the side of the tube. The urine will float on the nitric acid, and a white ring (precipitated protein) will appear at the junction of the two liquids. Sometimes the white zone does not appear until allowed to stand for a few minutes. Roberts' Test Using Roberts' reagent instead of mitric acid use the same procedure as in Heller's ring test. This test is more sensitive than the nitric acid test, but like Heller's test precipitates nucleoprotein and mucin. If a clear, white ring is not obtained at the contact zone, take another sample and run the "heat test." A cloudiness indicates albumin.

(b) SUGAR Small amounts (0 02 to 0 2 per cent) of reducing sugars may be present in normal urine, the nature of which is not understood. The presence of sugar in abnormally large amounts in the urine, called glycosuria, more frequently is the result of hyperglycemia (increased blood sugar), and less frequently the result of a low sugar threshold, called renal diabetes.

Benedict's Test To 5 ml of Benedict's qualitative solution in a test tube add not more than eight drops of urine, and, while agi tating the tube, boil from one to two minutes. Allow to cool spontaneously. The formation of a green, olive green, yellow, or red precipitate indicates the amount of sugar present, the amount being designated as plus  $1 (\frac{1}{2}\%$ , sugar), plus  $2 (\frac{3}{2}\%)$ , plus 3 (1%), and plus 4 (2% or more) respectively. If the amount of dextrose sugar is under 0.3 per cent the precipitate forms on cooling

Myer's Quantitative Determination (Optional) This determination is a modification of Benedict's method and is accurate enough for clinical purposes Pipette\* 5 ml of Benedict's quantitative solution into a large test tube (25 x 150 mm), and then add 1 to 2 Gm of sodium carbonate Using a folded piece of paper as a test tube holder held in the left hand, heat the solution to a vigorous boil, at the same time agitating the liquid Using a 2 ml Mohr pipette held in the right hand, carefully run the urine into the boiling solution a drop at a time, until a white precipitate begins to form Care must be taken at this point in adding the drops more slowly. The end point is reached when one drop clears up the last trace of blue color. Five ml of Benedict's solution will reduce 10 mg of glucose. The percent of glucose is found by dividing 1 by the number of ml 's of urine used.

(c) ACETONE BODIES The presence of acetone bodies in the urine, called acetonuria or ketonuria, is the result of incomplete oxidation of fatty acids due to a failure to "burn" carbohydrates Qualitative tests for acetone and acetoacetic acid are sufficient in

If unfamiliar with technique of using a pipette see Instructor

determining the existence of acidosis. The Rothera test detects both acetone and acetoacetic acid (1 in 20,000), while Gerhardt's test detects only acetoacetic acid (1 in 8000)

Rothera's Test for Acetone and Acetoacetic Acid Add a small crystal of sodium nitroprusside to 5 ml of urine, and shake until dissolved Slant the tube, and by means of a glass tube or pipette carefully stratify (arrange m layer) about 2 ml of concentrated am monium hydroxide upon the urine At the end of five or ten minutes a violet zone will develop at the junction of the two liquids, if acetone is present More than a trace of acetone is pathological

Gerhardt's Test for Acetoacetic Acid (Optional) To 5 ml of urine in a test tube, add ferric chloride solution (10 per cent), drop by drop, until a precipitate forms Filter and add a few more drops of ferric chloride solution A deep red color indicates acetoacetic acid

(d) BILE The presence of bile pigments in the urine is the result of obstruction to the flow of bile via the bile ducts into the intestine, and may be due to a calculus, catarrhal inflammation, or a growth of some kind Considerable amounts of bile impart a dark yellow color to urine, the foam of which upon vigorous shaking has a distinct yellow color Vigorously shake 5 ml of urine contained in a test tube

Gmelin's Test Carefully superimpose 5 ml of urine upon an equal quantity of "yellow" intric acid as in Heller's ring test for albumin. Upon standing for a few minutes and agitating very gently, a play of colors—green, blue, violet, red, and yellow will be seen in the presence of bilirubin.

Iodine Test Carefully superimpose dilute iodine (1 250) upon 5 ml of urine A green ring indicates bile

(e) BLOOD The presence of blood in the urine, called hematuria, indicates some lesion in either the kidney or in the urinary tract below the kidney When in large amounts blood imparts a reddish cast to urine The presence of blood is always pathological

Benzuline Test To a test tube containing 3 ml of a saturated solution of benzidine in glacial acetic acid, add an equal volume of hydrogen peroxide (3 per cent), and a few drops of urine A green to a deep blue color indicates the presence of blood

(f) INDICAN IN EXCESS: The presence of indican in the urine indicates excessive putrefaction taking place in the intestine as the result of bacterial action.

Obermayer's Test: To one-fourth of a test tube of urine add an equal volume of Obermayer's solution. Add 2 ml. of chloroform and mix by shaking. Upon standing the indican is changed to indigo, which dissolves and imparts a more than faint blue color to the chloroform. There is sufficient indican in normal urine to give a faint blue color to the chloroform in the presence of Obermayer's reagent.

(g) MICROSCOPIC STUDY (OPTIONAL): If time permits, examine microscopically the sediment obtained from pathological urines.

## EXERCISE 39—CHAPTER XXI BASAL METABOLISM TEST

Section . Date

Name

MATERIAL The Benedict Roth Metabolism Apparatus

As a laboratory experiment it is suggested that the class be given an opportunity of witnessing a basal metabolism test, and to study some of the charts made.

NOTE: The following material is largely obtained from Directions for Operating the Benedict-Roth Metabolism Apparatus, furnished by Warren E Collins, Inc.

## A. PRELIMINARIES TO THE METABOLISM TEST

(a) Instructions for the Instructor: Several days in advance of the experiment select one student of the group of students as the subject of the test. Measure the height of the student in centumeters, and obtain the weight of student (without clothing) in kilograms.

(b) INSTRUCTIONS FOR THE PATIENT: On the evening before the test eat lightly, and retire early (by 10 r.m.) to get plenty of rest Since digestion and absorption of food increase the rate of metabolism a basal metabolism can be determined only after about 14 hours of fasting

On the morning of the test avoid bath, dress slowly, do with as little muscular movement as possible, don't eat any breakfast or drink any liquid except water, avoid smoking, get to the place of testing with as little exertion as possible, and recline at least 20 minutes before starting the experiment. The metabolism rate will be elevated unless there is complete muscular and mental repose previous to the testing.

## B. EXPLANATION OF THE APPARATUS

The apparatus (Fig. 31) for measuring metabolism consists of a epitometer for holding pure oxygen with accompanying valves and tubes to allow rebreathing. The spirometer or oxygen bell is filled with oxygen, and the patient is connected to the metabolism tester by a mouthpiece. A nose clip is attached to the patient's nose and oxygen is inhaled from the spirometer through an intake valve (Fig. 32), and is exhaled through an expiratory valve back to the spirometer.

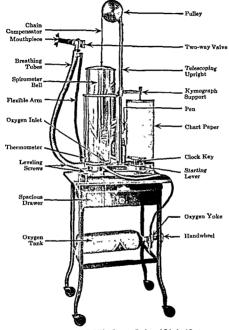


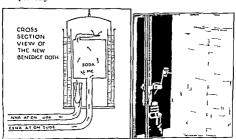
Fig. 31—Benedict-Roth Table, Oxygen Tank, and Principal Parts.



F'g 32-Mouthplece-Nose Clip-Valve

In the passage back to the spirometer the ex nured gas passes through an inside container filled with soda lime (Na2O, CaO) which absorbs the CO2 exhaled by the pa tient (Fig 33) The fall of the spirometer indi cates the oxygen con sumed The gradual de crease in the volume of oxygen in the spirometer and the respirations are graphically recorded by a writing arm of the am rometer, which makes

pen tracings over a chart fastened to a revolving drum (Fig. 34). The continuous series of upstrokes and downstrokes represent exhalations and inhalations respectively.



### DIRECTION OF RESPIRATIONS

Flg 33—Cross Section View Showing Direction of Respi ations

Fig 34-Pen and Counterweight

## C. MAKING THE METABOLISM TEST

Prepare the apparatus by putting on a chart, sterilize a rubber mouthpiece and fill the pen with ink. Have the patient recline on a couch in a comfortable position. Apply the nose clip well down on the nostrils and adjust the thumbscrew firmly. Have the patient test the airtightness of the nose clip by attempting to exhale through the nose. Connect the mouthpiece and allow the patient to breather own air through the slot in the free breathing valves for about one or two minutes. While allowing the patient to become accustomed to breathing through the mouthpiece fill the spirometer bell with oxygen, record the thermometer and the barometer reading. By

means of the valve handle connect the patient to the breathing circuit of the machine. Fromnowon, the spirometer will move up and down with each exhalation and inhalation, and the pen similarly. Set the clock in motion by moving its starting lever. Allow the test to run about eight minutes, and



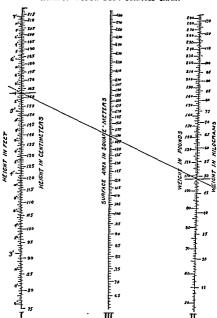
Fig 35—Drawing Slope Line.

repeat after a few minutes' rest with a second period to check the first test. Remove the chart, select the best consecutive six-minute section of each record, draw a line through the bottom peaks (Fig. 35). The slope of this line indicates the rate of oxygen consumption (in terms of calories per hour) which is easily read from the six one-minute lines which it intersects. Where the time line selected as the beginning of the test crosses the slope line, take a reading. Count six-minute lines to the left and take a second reading. Subtract the smaller from the larger and the difference is the patient's actual oxygen consumption (Fig. 36)

#### D. CALCULATIONS

(a) DETERMINATION OF NORMAL CONSUMPTION OF OXYGEN: Using a ruler, draw a line between the patient's height found in Column I and the weight in Column II. Read the Body Surface Area where the line intersects Column III. (This all refers to Table

TABLE A-DUBOIS BODY SURFACE CHART



(Prepared by Boothby and Sandiford of the Mayo Chinic.)

A) Transfer this body surface figure opposite "Column III" in the space for computations Refer to Table B and using the patient's age (nearest birthday) and sex read the calories per square meter per hour (Table B). Transfer the figure beside "Table B"

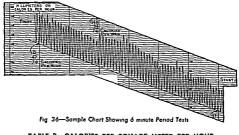


TABLE B-CALORIES PER SQUARE METER PER HOUR

Age	Males	Females	Age	Males	Females
5	(53 0)	(51 6)	20-24	41 0	36 9
6	52 7	50 7	25-29	403	366
7	520	493	1		1
8	51 2	48 1	30-34	398	36 2
9	504	469	35-39	39 2	358
	ļ	i '	1	1	
10	495	458	40-44	383	353
11	486	446	45-49	378	35.0
12	478	434	1	1	i
13	471	420	50-54	372	345
14	462	410	55-59	366	341
	!	1	<b>!</b>	ļ	i
15	453	396	60-64	360	33 8
16	447	38.5	65-69	35 3	33 4
17	437	37 4	l !		1
18	429	373	70-74	(34.8)	(32 8)
19	42 1	372	75-79	(34 2)	(32.3)
			h !		' '

in space for computations Multiply III x B which will give the total Normal Calories Per Hour—the exact normal oxygen consumption for a person of this height, weight, age, and sex

(b) DETERMINATION OF ACTUAL CONSUMPTION OF OXYGEN Transfer the difference in heights of the six minute test period to the space provided for 1t opposite O<sub>2</sub> line Record the temperature of the spirometer and barometric pressure Using the Table C

# TABLE C-CORRECTION FOR TEMPERATURE AND PRESSURE

```
Temperatura in decrees Centierada
mm 15 16 17 18 19
                         20 21 22 23 24
                                              25 26 27 28 29
                                                                   30 31 32 33 34 35
600 735 732 728 725 721 718 715 712 708 704
                                              701 697 693 689 685
                                                                   681 677 673 569 665 661
605 742 739 736 731 727 724 721 718 714 710
                                              207 203 699 695 691
                                                                   687 683 679 675 671 665
610 748 745 741 737 733 730 727 724 720 716
                                              713 709 70., 701 697
                                                                   693 689 685 680 676 672
615 754 751 747 744 740 737 734 730 726 722
                                              719 715 711 707 703
                                                                   699 695 691 686 682 678
620 760 757 753 750 746 743 740 737 733 729
                                              725 721 717 713 709
                                                                   705 701 696 692 688 684
625 767 764 760 756 752 749 746 743 739 735
                                              731 727 723 719 715
                                                                   711 707 702 698 694 690
630 773 770 766 762 758 755 752 749 745 741
                                              737 733 729 725 721
                                                                   717 713 708 704 700 696
635 779 776 772 768 764 761 758 755 751 747
                                              743 739 735 731 727
                                                                   723 719 714 710 705 702
640 783 782 778 774 770 767 764 761 757 753
                                              749 745 741 737 733
                                                                   729 725 720 716 711 707
645 792 788 784 781 777 773 770 767 763 759
                                              755 751 747 743 739
                                                                   735 731 726 722 717 713
650 738 794 791 787 784 780 777 773 769 765
                                              761 757 752 748 744
                                                                   740 736 732 727 723 719
655 804 800 797 793 790 786 783 779 775 771
                                              767 763 758 754 750
                                                                   746 742 738 733 729 724
660 810 806 803 799 796 792 789 785 781 777
                                              773 769 764 760 758
                                                                   752 748 744 739 735 730
665 816.812 809 805 802 798 795 791 787 783
                                              779 775 770 766 762
                                                                   758 754 749 745 741 796
670 822 819.816 812 809 805 801 797 793 789
                                              785 781 776 772 768
                                                                   764 760 755 751 748 742
675 828 825 821 818 816 811 807 803 799 795
                                              791 787 782 778 774
                                                                   770 766 761 757 752 748
680 834 831 827,824 821 817 813 809 805 801
                                              797 793 788 784 780
                                                                   776 771 767 763 758 754
685 841 837 833.830 827 .823 819 815.811 807
                                              803 799 794 790 786
                                                                  782 777 773 769 764 760
690 848 844 841 837 833 .829 825 821 817 813
                                              809 805 800 796 797
                                                                  788 783 779 775 770 765
695 R54 850 847 843 839 R35 831 827 R23 819
                                              815 811 806 802 798
                                                                  794 789 785 780 776 771
700 860.856.853 849.845 841 837 833 829.825
                                              821 817 812 808 804 .800 795 791 786 781 777
705 866 862 859 855 851 847.843.839.835 831
                                              827 823.618 814.810 806 801 796 792 787 783
710 872 868 865 861 857 853 849 845 841 837
                                              833 829,824 820 816 ,812 807 802 798 793 788
715 878 874 871 867 863 859 855 851 847 843
                                              839 835 830 826 822 818 813 808 804 799 704
720 885 881 877 873 869 865 861,857 853 849
                                              845 841 836,832 828 824,819 814 810 805 R00
725 891 887 883 879 876 ,872 867,863 859 855
                                              851 847 842 838.834 .830 825 820 816 811 806
730 897 894 890 886 882 878 874 869 865 861
                                              857,853 848,844,840 ,836 831 826 822 817 819
735 ,904 900 896 892 888 ,884 880 875 871 867
                                              863 859 854 850 848
                                                                  842 837 832 827,822 817
740 910 906 902 898 894 890 886 881.877 873 ,869 865 860 858 852
                                                                  848 843 838 833 828 823
745 916 912 908 904 900 896 892 887 883 879 875 871 866,862 857
                                                                  853 R48 844 839 834 829
750 922 918 914 910 906 902 898 893 889 885 .881 877 872 868 863 859.854 849 845 840 835
755 928 924 920 916 912 908 904 899 895 891 887 883 874 869 .865 860 855 851 846 841
760 934 930 926 922 918 914 910 905 901 897 893 889 884 880 875 871 866 861 857 852 847
765 941 936 932 928 924 920 916 911 907 903 ,899 895.890 886 881 877 872 867.863 857 852
770 947 943 939 935 930 926 922 917 913 909 905 901 896 892 887 .883 878 873 869 863 858
775 954 949 945 941 936 932,928 923 919 915 911 907 902 898 893 889 884 879 875,869 864
780 960 956 952 948 943 939 935 930 926 921 917 913 908 904 899 ,895 890 885 880 875 870
```

draw a circle around the temperature and the barometer readings and at the intersection of these two columns you will find the correction factor Transfer this figure opposite "Table C' in space provided for computations Multiply the difference in height for the six minute test period (from kymograph tracing) by O line by Table C which will rive the total actual Test Calories Per Hour (c) DETERMINATION OF BASAL METABOLIC RATE: To find the relation of the Normal Calories Per Hour to the Actual Test Calories Per Hour in terms of per cent subtract the smaller from the larger, and divide the difference by the normal, and multiply by 100 This is the Basal Metabolic Rate in per cent. If the Actual test is greater than the Normal the result is plus, and if less the result is minus

DATA AND COMPUTATIONS

Sar	nple	Patient		
Name	Date	Name	Date	
Age 49 Yrs 4 Mo	Height 5' 4"	Age Yrs	Mo Height	
Wt 108 lbs		Wt		
Temperature Barometer		Temp Bar Press		
Normal	Actual Test	Normal	Actual Test	
Column III ≈1 50	O₂ line ≈ 74	Column III =	O2 line =	
Table B = 35	Table C = 0 902	Table B =	Table C =	
III × B ≃52 5	O2 × C = 66 748	III × B =	02 × C =	
$\frac{6675 - 525}{526} = +27 \text{ B M R}$		BMR ==		
Pulse 72-70		Pulse		
Body Temperature 98 0		Body Temperature		
Blood Pressure 110-80		Blood Pressure		

Does the calculated basal metabolism of the subject fall within 10 per cent of the theoretical? Suggest reasons why the percentage deviation of the basal metabolism as carried out is likely not to be a true record of the basal metabolism

## E. SPECIFIC DYNAMIC ACTION OF PROTEIN

As an interesting sequel to the determination of the basal metabolism the following experiment can be performed.

Feed the same pseudo-patient 250 Gm. of fried chopped meat, and at the end of one hour's rest repeat the metabolic determination.

	Data	Computation
Temperature	-	
Bar, Press.	=	
O2 line		
Table C	=	
02 × C		
B.M.R.		
Pulse	-	
Body Temp.	=	
Blood Press.	==	1

Is there any specific dynamic action produced by proteins?

### F. CONDITIONS AFFECTING METABOLIC RATE

The following list gives the most common conditions which influence the metabolism test and show an increased or decreased metabolic rate.

### Increased Metabolic Rate in

- 1 Hyperthyroidism
- 2 Hyperpituitarism, Acromegaly, Gigantism
- 3 Leukemia Lymphatic and Myelogenous
- 4 Anemia, when severe 5 Malignancy, in about 30 per
- o Maiignancy, in about 30 p
- 6 Hodgkin's Disease
- 7 Diabetes, when moderate
- 8 Acadosis, when severe 9 Arterial Hypertension 10 Fever 7 per cent increase for
- each °F of rise of body temperature (DuBois)
- 11 Convalescence from wasting diseases, and rapid growth

### Decreased Metabolic Rate in

- 1 Post-Thyroidectomy
- 2 Myxedema
- 3 Cretinism 4 Thyrogenous Obesity
- 5 Hypopituitarism
- 6 Hypophyseal Obesity
- 7 Hypoadrenalism 8 Addison's Disease in about 15
- per cent of cases
- Undernutration, Starvation
   Epilepsy
- 11. Arterial Hypotension
  - 12 Nephrosis

## G. SOME TYPES OF RESPIRATIONS

Determinations of the Metabolic Rate show the character of respirations. The following spirograms show types associated with some common disorders.



Fig 37-Normal.



Fig 38-Toxic Goster



Fig 39-Cardiac Difficulty

# EXERCISE 40-CHAPTER XXIII

Section

Dota

Name

MATERIAIS Hydrometer (lactometer or urnometer), whole and slimmed milk, copper sulfate solution (I per cent), 10 per cent acetic acid, 95 per cent alcohol, ether, junket tablets, Benedact's solution, ammonium molybdate solution, sodium alcoholate (10 per cent alcoholic solution of sodium hydroxide), ammonium avalate solution

#### A. GENERAL CONSIDERATIONS

- 1. REACTION: Test the reaction of fresh whole milk with red and
- blue litmus paper. Is it acid, basic or neutral?
- SPECIFIC GRAVITY: The specific gravity of normal cow's milk should not be lower than 1 029 at 60° F., if legal. Using a hydrometer take the specific gravity of both whole and skimmed milk.

The sp gr. of whole milk is

, of skimmed milk is

The difference is due to

How could skimmed milk be cheaply changed so as to have the same sp. gr. as whole milk?

3 Film Formation: Pour a test tube of whole milk into an evaporating dish and heat until a scum forms on top of the milk Recalling the action of white of an egg in very hot or boiling water,

what same nutrient in milk is shown by coagulation?

Remove some of the scum with a stirring rod and place in a test tube Make the buret test by adding 5 ml of 10 per cent sodium hydroxide solution, and then carefully add a few drops of very dilute copper sulfate solution down the side of the inclined tube

The result indicates the presence of

### B. SEPARATION OF CONSTITUENTS

1. CASEIN AND FAT SEPARATION: To a mixture of 50 ml. of whole milk and 50 ml. of water in a beaker, slowly add 10 per cent acetic acid, drop by drop, with constant stirring, until a flocky precipitate (casein and fat) separates and leaves a clear solution upon standing. Too much acid prevents the separation. What acid ordinarily

sours and curdles milk?

What home nutrient is made from curd formed when milk sours?

Allow the curd to settle, filter, and save the whey (filtrate containing lactalbumin, mineral salts, and lactose) for 2.

(a) Casein: Remove the curd from the wet filter paper and press it as dry as possible between several thicknesses of dry toweling paper (or filter paper). Make the biuret test on a small portion.

Result shows the presence of Transfer the remaining curd to a test tube, cover with one-half a test tube of 95 per cent alcohol to remove adhering water. Shake it thoroughly and then discard the alcohol.

(b) Fat: Cover the curd again but this time with one-half a test tube of ether. Turn out all gas flames near ether as the vapors ignite very readily. With a glass rod stir the ether-casein-fat mixture for a minute or more. Pour the ether, or filter the ether extract into an evaporating dish. Allow the ether to evaporate spontaneously. Blowing upon the ether will hasten the evaporation. When no more ether will evaporate, make a spot with a drop of the residue on paper, hold up to the light and observe the translucent, greasy appearance of the fat. Dissolve the remaining fatty residue in 5 ml. of ether. Add 2 ml. of soldium alcoholate, carefully evaporate the ether, and then add 5 ml. of water. Pour into a test tube, add a piece of litmus paper, and then add H<sub>2</sub>SO<sub>4</sub>, drop by drop, until acid. Note the odor of volatile fatty acids. The odor is mostly

due to acid.

(c) Rennin Precipitation of Casein: As stated elsewhere, casein may also be precipitated by rennin. Fill a test tube about threefourths full of whole milk and warm it to a little above body temperature by placing in a beaker of warm water (40 to 45° C.). Dissolve a small amount, about one-tenth of a junket tablet, in 1 ml. of cold water, add it to the warm milk and allow to stand

quietly for several minutes. Result?

Commercial case in made in this way and treated with the proper bacteria is used to make what nutrient?

2. LACTALBUMIN: Place the whey (acetic acid filtrate saved from 1) in an evaporating dish and boil for at least a minute. Lactalbumin not precipitated by acetic acid will now be rendered insoluble. Filter and save the filtrate for the lactose and phosphate experiment. Of the two proteins in milk, lactalbumin differs from

casein by being coagulated by and not by dilute acids. Make the biuret test on the precipitated lactalbumin.

### Result?

- 3. LACTOSE: To one-half of the filtrate saved after the removal of albumin add 1 to 5 ml. of Benedict's solution and boil. The solution must be alkaline to litmus A yellowish precipitate indicates the presence of lactose, and shows it has properties.
- 4. Phosphate. To the remaining half of the filtrate saved from the former test add about one-tenth of its volume of nitric acid. If a precipitate forms it is uncoagulated albumin and must be removed by filtration. Now add ammonium molybdate solution.

warm, and allow to stand The color of the precipitate is

and indicates the presence of a , which occurs as a salt of calcium in milk.

5. CALCIUM (OPTIONAL): Carefully evaporate 10 ml. of milk almost to dryness in an evaporating dish. Remove the wire gauze, add 2 ml. HNO3, and heat directly with the flame until all the charred carbon has been oxidized to a white ash. To remove the last traces of unchanged carbon, hold the burner in your hand and direct the flame on the inside of the dish. Add 1/2 test tube of dis-

tilled water. Is the ash (inorganic) entirely soluble? Add about ten drops of HCl, heat to boiling, and filter into a test tube. Using a piece of litmus paper as an indicator make the filtrate just basic with NH<sub>4</sub>OH, and then just acid with acetic acid. To this solution add about 5 ml. of ammonium oxalate solution.

Calcium is slowly precipitated. Allow the test tube to stand undisturbed for 15 minutes, and then notice the amount of white precipitate. From your observation would you conclude that

the amount of calcium in milk is high or low?

In what foods is calcium conspicuously absent?

A calcium deficiency in the diet results in poor development of

## LABORATORY APPENDIX

- I. Chemicals Required
- II. Desirable Apparatus and Supplies
- III. General Rules for Solubility
- IV. Solubility Table
- V. First Aid

## I. CHEMICALS REQUIRED FOR A MINIMUM OF FIFTY STUDENTS

(It is economical to buy in large quantities because the relative price of larger quantities is much less than when purchased in small quantities)

```
Quantity
                               Description
           Acid, Acetic, 99 5 per cent, glacial C P
 1 lb
 8 oz
           Acid. Butyric. 98 per cent. C P
12 lb
           Acid, Hydrochloric, sp gr 1 19, in 6 lb bottles, C P
 1 liter
           Acid, Hydrochloric, N/10
14 lb
           Acid, Nitric, sp gr 142, in 7 lb bottles, C P
           Acid. Oleic, U S P
 1 02
 1 lb
           Acid, Oxalie, C P
           Acid. Picric. C P
 2 02
 4 oz
           Acid, Salicylic, Crystals, C P
18 lb
           Acid, Sulfuric, sp gr 184, in 9 lb bottles C P
           Acid, Tannic, C P
 4 oz
           Acid, Tartaric, Crystals
 8 02
 8 oz
           Albumin, dry egg
 1 lh
           Alcohol, Amvi. C P
           Alcohol, Ethyl 95 per cent, U S P
 1 gal
           Alcohol, Methyl, C P
 1 at
           Alkacid or Nitrazine test papers
 6 vials
 4 07
           Aluminum Sulfate C P
           Ammonium Chloride, C P
 4 07
           Ammonium Hydrate, C P sp gr 0 90, in 4-lb bottles
 8 lb
           Ammonium Molybdate
 4 02
 4 02
           Ammonium Oxalate, C P
  1 lh
           Ammonium Sulfate, C P
  1 lb
           Ammonium Tartrate, C P
  1 lb
           Amyl Acetate, pure
           Barium Chloride, C P
  4 oz
  1 at
           Benedict's Solution qualitative
            Benedict's Solution quantitative
  1 pt
            Benzidine
  8 oz
  1 lb
            Calcium Carbonate Chips (marble)
            Calcium Chloride Anhydrous C P
  4 02
  4 oz
            Calcium Hydroxide
  3 lb
            Calcium Hypochlorite technical (bleaching powder)
  2 lb
            Calcium Oxide (quicklime), lump
            Calcium Phosphate, pwd.
  1 oz
  4 07
            Calcium Sulfate, calcined (plaster of Paris)
  4 oz
            Camphor, refined
  4 lb
            Carbon Disulfide, C P, in 1 lb bottles
  3 lb
            Carbon Tetrachloride, pure
  4 02
            Casem (dry)
  1 lb
            Charcoal, Wood, animal
  4 oz
            Charcoal, Wood, stick, for blow pipe
```

```
Quantity (Continued)
                               Description (Continued)
 2 lb
           Chloroform, U S P
 3 02
           Coffee
 1 lh
           Collodion (or cellophane sausage skins)
           Copper Metal, chips or punchings
 4 nz
           Copper Metal Wire, No 14, for making spiral
 4 07
 4 07
           Copper (ic) Chloride, crystals, C P
 4 07
           Copper (ic) Oxide, powder, black, technical
 1 07
           Copper (ic) Oxide, granular, C P
 2 lb
           Copper (1c) Sulfate crystals, U S P
 4 02
           Dextrose, crystals C P
 2 lb
           Ether, Ethyl, U S P. in 1 lb cans
 8 07
           Folin Wu Blood Sugar reagent
 1 lb
           Formaldehyde, 40 per cent solution, C P
 1 at
          Gasoline
 4 oz
           Gelatin, granular
 4 01
           Gelatin, Sheet
 4 07
           Glycerol, U S P
 Al A
           Hydrogen Peroxide, U S P, 3 per cent, in 1 lb bottles
 4 oz
           Iodine resublimed, C P
 2 lb
           Iron Powder
 4 07
           Iron (1c) Chloride, C P lumps
 1 lb
           Iron (ous) Sulfate, crystals, pure
 2 07
           Iron (ous) Sulfide lump
 4 02
          Junket tablets
 1 lb
          Karo Syrup
 1 lb
          Lactose (milk sugar), powder, C P
 4 07
          Lead Acetate, normal, crystals, C P
 4 07
          Litmus, cubes
 8 07
           Magnesia Mixture
 1. oz
           Magnesium Metal, ribbon, 1/2 in wide
 1 lh
           Magnesium Sulfate, crystals (Epsom salt)
 t lh
           Manganese Dioxide, C. P., powder
 1 oz
           Mercuric Oxide
10 or
           Mercurochrome, crystals or tablets
 1 lb
           Mercury (1c) Chloride, crystals C P
 4 oz
           Mercury (1c) Nitrate, C P
 4 02
           Mercury (ous) Nitrate, C P
 8 02
          Obermayer's solution
 2 lb
           Oil, Cottonseed
 Loz
           Pancreatin, pure, powder
          Pepsin, U S P, powder
 1 oz
 1 oz
          Phenolphthalem, pure
 1 oz
          Phenylhydrazine hydrochloride
 1 oz
          Phosphorus, yellow, sticks
          Platinum Metal, wire, No 24
 6 ft
 2 oz
          Potassium Bisulfate, crystals, C P
 1 lb
          Potassium Bitartrate, powder, USP
 4 oz
          Potassium Bromide, C P
```

Quantity	(Continued) Description (Continued)
2 lb	Potassium Chlorate, crystals, C P
4 oz	Potassium Chloride, C P
1 lb	Potassium Dichromate C P
4 oz	Potassium Ferrocyanide, C P
4 oz	Potassium Hydrogen Sulfate
1 lb	Potassium Hydroxide, sticks purified
8 oz	Potassium Iodide, crystals, C P
1 oz	Potassium Metal, balls
2 lb	Potassium Nitrate, fine crystals
4 02	Potassium Oxalate, powder
4 oz	Potassium Permanganate, C P
4 oz	Potassium Phosphate, C P
1 oz	Potassium Thiocyanate, C P
4 oz	Quinine
4 oz	Qumine Sulfate
25 Gm	Resorcin, Resublimed, C P
8 oz	Roberts' Reagent
1 lb	Saccharose, crystals, C P
4 oz	Silver Nitrate, crystals, U S P, C P
1 pt	Soap Solution
1 lb	Soda Lune, granular, pure
2 lb	Sodium Bicarbonate powder, C P
1 lb	Sodium Borate, powder, C P
2 lb	Sodium Carbonate, anhydrous, C P
5 lb	Sodium Chloride, pure (table salt)
5 lb	Sodium Hydroxide, sticks C P, in 1 lb bottles
2 lb	Sodium Hyposulfite ("hypo"), crystal; C P
2 oz	Sodium Metal
1 oz	Sodium Nitroprusside, C P
4 oz	Sodium Phosphate, dibasic, crystals, C. P., secondary
1 lb	Sodium Phosphate, tribasic
4 oz	Sodium Potassium Tartrate Crystals, C P
4 oz	Sodium Sulfate, crystals, C P
1 oz	Sodium Tungstate
2 liters	
2 1Ь	Starch, Corn
1 lb	Steel Wool
1 lb	Sugar, Cane C P
8 oz	Sugar, Grape (dextrose)
2 oz	Sugar, Milk. Sulfur, Roll (brimstone), powder
2 lb	Tea
4 oz	Tea Turpentine
1 qt 1 lb	Zinc Metal, mossy, technical
T 10	Anic metal, mossy, econocar

1 ball 24

4

24

24

## II. DESIRABLE APPARATUS AND SUPPLIES

In addition to the individual list of apparatus, page 638, for each student, the following general apparatus and supplies will be found desirable

•	- S g
Quantity	Description
1	Balance, inverted beam type, or triple scale triple beam type
1	Bit, No 13, 1/2 inch diameter
24	Bottles, dropping, Hood stopper, 2000 ml
Optional	
24	Candles (birthday)
1	Centrifuge (small table model)
24	Centrifuge tubes
1 yd	Cloth, muslin
1 lb	Coal, soft
100	Corks to fit bottles (6 oz )
300	Corks to fit test tubes.
1 spool	Cotton Thread, No 10
2	Cylinder, graduated, 100 ml
1	Cylinder, graduated 500 ml
6	Fermentation Tube, on foot, small
12	File, triangular, 5 in
2	Forceps, steel, 4 m
15 ft	Glass rod, diam 5 mm
60 ft	Glass tubing, diam 6 mm
1	Graduate, cylindrical, 1000 ml.
2	Graduate, cylindrical, 250 ml
1	Graduate, cylindrical, 500 ml
1	Knife, paring
1	Lancet, spring clamp, adjustable length
12	Magnet bar, length 15 cm
12	Magnifiers, reading glasses diam 2½ in , with handle
72	Medicine droppers
1	Microscope
24	Mohr pipette, 2 ml
1 yd	Muslin, bleached
24	Needle holder, of brass nickel plated, adjustable screw chuck
1	Scissors
1 spool	Silk thread, white, heavy
24	Sules and cover glasses
2	Splint Wood, 100 in package.
6	Spoons, horn, length 4 in
6	Spoons, horn, length 6 m
2	Spoons, horn, length 8 in
1 ball	String (cotton)

Test tubes, 5 inch, with sidearm Test tubes (25 x 150 mm)

Thermometers, 10° to 110° C

Unnometer.

Quantity (Continued)

Description (Continued)

4

Vogel Scale 24 Wing tops for burners

1 skein Wool darning varn white

### III. GENERAL RULES FOR SOLUBILITY

- (a) All sodium, potassium, and ammonium compounds are soluble in water
  - (b) All nitrates, chlorates and acetates are soluble in water (c) All chlorides are soluble, except those of silver, mercury
- (mercurous), and lead (lead slightly soluble) (d) All sulfates are soluble, except those of lead, barrum, stron
- trum and calcium (calcium slightly soluble) The silver and the mercurous sulfates are only moderately soluble (e) All carbonates are insoluble, except those of sodium, potas
- sium, and ammonium
- (f) All oxides and hydroxides are insoluble, except those of ammonum, sodium, potassium, and barium, calcium hydroxide is slightly soluble

### IV. SOLUBILITY TABLE

Since no salt is absolutely insoluble, the term "insoluble" is only relative (Scott's Standard Methods of Chemical Analysis, D Van Nostrand Co.)

Cation	15,	ζ	Br'	ù	CN,	NO3	C103'	C2H3O3'	s,	,,º02	SiO3"	"*os	CrO*"	(BO <sub>2</sub> ' (BO <sub>2</sub> '	,,'Od	AsO.,'	AsO <sub>3</sub> ′′	Fe(CN),""	Fe(CN),"	OH,
ĸ	w	w	w	w	w		w	w	w	w	w	w	w		w		w	w	w	w
Na*	W	W		w		w			w		w	w	w		w		W	W	w	w
Lı	w	w		w	w		w		w	w	w	w	w	w		w	W	w	w	w
Ba	wa		W	w	wA		w		w	A	Α	1	A	Α	Α	A	Α	-	wA	-
Sr	wa			w	w		W	W	w	A	Α	1	wA	A	A	Α	A	-	w	_
Ca	wa			w	W	w		w	w	A	Α			A	Α	Α	A	w	w	wA
Mg			W	w	w		w	wA	w	A	Α	w	w	wA			A	w	w	l –
Al	w		W	w	-		W	w	-	-	wa	w	-	A	Α	Α	-	-	-	
Mn	A		w	W	A			wA	A	A	Α	W	w	Α	A	Α	Α	I	A	-
Zn	wA		w	W	A		w	w	Α	Α	A	W	w	Α	A	A		A	wa	-
Cr	w		W		A	w	w	wA	1-	-	A	w	A	A	Α	A		-1	-	-
Cd	wA			W	Α		w	w	A	A	Α	w	w	wA	A	~	-		-	-
Fe	wA			W	wa			w	A	Α	Α	W	-	A	Α	A	A	1	I	-
Fe	w			-	-		w	A	-	-	A	W	w	Α	A	Α	Α	w	1	-
Co	wΑ			w	wa		W	W	Α	Α	Α	w	Α	Α	A	Α	A	1	1	-
Nı	wA			W	wa		W	w	Α	A	A	W	A	A	A	A	Αļ	1	1	-
Sn	w	W		w	-	w	w	Α	A	1-1	-	w	A	A	A	-		1	I	-
Sn	w	W		w	-	-	-	-	A	-	A	-	- 1	-	A	A	A	-1	Ι	-
PЬ	A.		w	w	A		w	W	A	Α	Α	1	I	A	A	Α		wA	A	-
Cu.	A		W	1	I	w	w		A	A	-	w	w	A	A	Α	A	- 1	1	-
Sb	w	A				<b> </b> -	1	A	A	1-	- 1	A	A	- 1	A	A	-1	-1	-1	-
Bı	w	A		Α	-	A	w	A		A	A	A	A	Α	A	Α	-1	- 1	-	-
Hg	١	Ш	1	I	-	w	W	A	۱-	A	-	wA	A	-	A	Ą	Ą	-	-1	
Hg	WΑ	W		A	w	ĮΨ	W	A	A	Α	I -	w	wA	-	A	A	Ą	_	- I	_
Ag	w	I	1	Ī	I		w	A		A	A	wΑ	Α	Α	A	A	A	A	1	-
Pt	-		w	1	w	w	1-	-	A	J –	I –	w	J -	- 1		~	A	- [	-	
Au	[-	100	W	A	w	[-	[-	[~	^	[~	-	_	[-	-		_[	-1	-(	-1	_

ABBREVIATIONS W, soluble in water, A, soluble in acids wA slightly soluble in water, readily soluble in acids wa, difficulty soluble in water and in acids, I, insoluble in water and acids The metals are arranged in order of their electromotive series

### V. FIRST AID

A first aid cabinet\* should be in every laboratory. At least the following materials should be on hand for the *immediate* treatment of burns and cuts

- (a) Cotton-1/2 pound roll
- (b) Plain sterile gauze-to apply to wounds and burns
- (c) Sterile gauze bandages-2 inches by 10 yards
- (d) Adhesive tape-1/2 inch by 10 yards
- (e) Sodium bicarbonate (baking soda), tannic acid jelly, or pictic acid burn emollient. (These substances are used for burns)
- (f) Saturated borne acid solution—this is about one teaspoonful of borne acid to a glass of water
  - (g) Tincture of iodine, 3 per cent
- (h) Aspirin tablets, five grains each (Two tablets may be given for pain pending the arrival of the doctor)
  - (i) Aromatic spirits of ammonia
- (j) Tourniquet to stop hemorrhage (A length of rubber tubing makes an excellent tourniquet A tourniquet should be loosened every few minutes or there is danger of causing gangrene)

### BURNS

Burns are classified into three degrees In a first degree burn, associated with redness, the skin is never broken in a second degree burn a blister occurs while in a third degree burn there is a destruction and involvement of the tissues below the burn. Never use oil or any greasy substance on badly blustered or broken skin, because of the danger of infection, and interfering with the treatments listed below or those of a physician.

On a burned area are formed tous substances, which upon absorption injure the kidneys. In severe cases of burns death results, due to uremia Tannic acid or pierce acid prevents the absorption by precipitating the injured tissues and forming a firm coagulum over the surface, and thus prevents the absorption of these toxic proteins, and at the same time acts as an antiseptic, as well as relieving pain by excluding air. Days later when the coagulum separates it leaves a healed epidermis in superficial burns, and a clean granulating surface in deeper burns.

From Heat. Dress with either of (e) and handage

From Acids Wash thoroughly with water, treat with dilute sodium bicar bonate (5 per cent solution) and bandage

From Alkalies Wash thoroughly with water, treat with (f) and bandage In the Eye Wash thoroughly with water, treat with dlute sodium bicarbonate (5 per cent solution) if an acid burn or (f) if an alkali burn

#### CUTS

From Glass Wash with water, treat with (g) and bandage

<sup>\*</sup> First Aid Cabinet prepared by the Fisher Scientific Co , Pittsburgh, Pa , which company has for distribution an excellent Laboratory Emergency Chart.

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